



RIVER BIRDS OF PREY AREA 1992 ANNUAL REPORT

Research and Monitoring



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**SNAKE RIVER BIRDS OF PREY AREA RESEARCH
AND MONITORING
ANNUAL REPORT**

1992

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PREFACE

This report summarizes research and monitoring activities in the Snake River Birds of Prey Area (SRBOPA) during calendar year 1992. As in previous years the main research effort in the SRBOPA was the BLM/IDARNG Research Project.

RRTAC Activities

A significant action in the Raptor Research and Technical Assistance Center (RRTAC) was hiring Dr. Mark Fuller as Director in July 1992. Dr. Fuller came from the U.S. Fish and Wildlife Service (USFWS), Patuxent Wildlife Research Center. Upon the retirement of Dr. Tom Cade from the Raptor Research Center at Boise State University (BSU) in Spring 1993, Dr. Fuller will oversee both BLM and BSU functions of RRTAC. RRTAC's main effort in 1992 was conducting the cooperative BLM/IDARNG Research Project and coordinating other research and monitoring in the SRBOPA. In 1992 RRTAC also conducted numerous technical assistance actions, primarily requests from the RRTAC literature systems.

BLM/IDARNG Research Project

Field Studies: This was the second year of intensive field work for the 5 component studies of this 6-year research project (Table 1). Studies were at full intensity with some 75 people in the field. Results of these efforts are presented in the first half of the progress reports of this volume.

Project Integration: Principal accomplishments of the 1992 Integration effort include: conducting a Project Integration Workshop, developing a protocol for constructing the habitat map from satellite imagery, and review of 1992 annual reports and 1993 study plans for each component study. Final annual reports are presented in this volume, and revised versions of the 1993 study plans will appear as addenda to the original study plans in the 15 January 1991 Research Plan for the Project. A report of the integration effort is presented in the first half of this volume.

Other Research and Monitoring in the SRBOPA

Considerable work other than the BLM/IDARNG research continued in the SRBOPA. In 1992, BLM staff and cooperators continued, initiated, or completed 16 studies. This year, graduate studies were initiated on sex ratios of American kestrels, nest box use of northern saw-whet owls and prairie falcon post-fledging mortality. Also a pilot study was conducted on Townsend's ground squirrel dispersal. Scott Grothe completed his M.S. thesis in 1992. These and the continuing studies are reported in the second half of the progress reports of this volume.

Table 1. Component Studies of the BLM/IDARNG Research Project

Study 1. *Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas.* Tom J. Cade, Christine Watson, and Katherine Strickler, Principal Investigators. Raptor Research Center, Boise State University.

Study 2. *Raptor Habitat Use and Foraging Behavior.* John Marzluff, Principal Investigator. Greenfalk Consultants.

Study 3. *Raptor Nesting Densities and Reproductive Success.* Michael N. Kochert, Robert N. Lehman, and Karen Steenhof, Principal Investigators. Raptor Research and Technical Assistance Center, BLM.

Study 4. *Townsend's Ground Squirrel Abundance, Productivity, and Habitat Relationships.* Beatrice Van Horne, Principal Investigator. Colorado State University.

Study 5. *Vegetation Classification/Description and the Ability of Soils/Vegetation to Support Ground Squirrel and Jackrabbit Populations.* Steven T. Knick, Principal Investigator. Raptor Research and Technical Assistance Center, BLM.

Study Integration John Rotenberry, Principal Investigator.
University of California, Riverside.

Technical Advisory and Review Panel

Michael Collopy, BLM Cooperative Research Center, Corvallis, Oregon;

Brian Maurer, Brigham Young University, Provo, Utah;

Graham Smith, U.S. Fish and Wildlife Service Office of Migratory Bird Management, Patuxent, Maryland; and

Jay Anderson, Idaho State University, Pocatello, Idaho.

RRTAC staff implemented certain studies and maintained cooperative efforts with other agencies, private industry, and individuals. RRTAC studies included assessment of nest box use by American kestrels and the continuation of Global Climate Change research. Another BLM study involved use of nest boxes in the SRBOPA by the Bruneau Resource Area. RRTAC also conducted a passerine bird study in the SRBOPA in cooperation with the USFWS, Patuxent Wildlife Research Center. Cooperative studies continued with Jim Munger, BSU; Carl Marti, Weber State University; John Marzluff, Greenfalk Consultants; and Helen Ulmschneider, USFWS.

Long-term monitoring activities also continued in the SRBOPA. Townsend's ground squirrel and black-tailed jackrabbit monitoring was part of Study 5 of the BLM/IDARNG Research Project. IDARNG again conducted monitoring activities in the Orchard Training area, and the Idaho BLM State Office also monitored greenstrips within the SRBOPA.

Technology Transfer

Although the main thrust for 1992 was conducting the BLM/IDARNG Research Project and continuation of cooperative research projects, work still continued on Technology Transfer. Ten scientific papers were published and/or accepted for publication in 1992, and BLM RRTAC staff and associates made 26 technical presentations at various meetings and workshops.

ACKNOWLEDGMENTS

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COOPERATING AGENCIES AND INSTITUTIONS

Albertson's College of Idaho
Boise State University, Raptor Research Center
Colorado State University
Greenfalk Consultants
Idaho Army National Guard
Idaho Department of Fish and Game
Idaho Department of Transportation
Idaho Department of Water Resources
Idaho Power Company
Idaho State University
Pacific Power and Light Company
Peregrine Fund; World Center for Birds of Prey
University of Idaho
U.S. Army Chemical Engineering and Research Center
U.S. Army Corps of Engineers, CERL
U.S. Fish and Wildlife Service
 Office of Migratory Bird Management
 Patuxent Wildlife Research Center
 Boise Field Office
U.S. Forest Service Intermountain Research Station
Weber State University

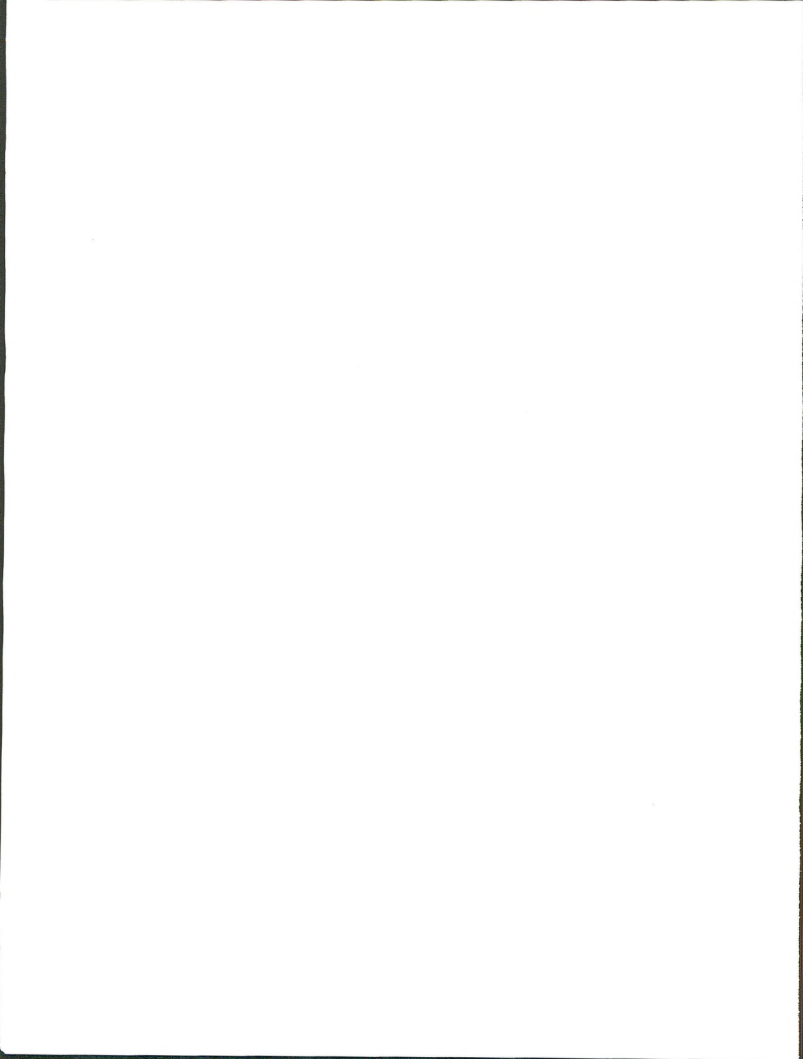


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PART I
TECHNOLOGY TRANSFER

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* Published and/or accepted for publication in 1992. Reprints of most of these articles are available from the Raptor Research and Technical Assistance Center, Bureau of Land Management, 3948 Development Avenue, Boise, ID 83705.

1992 RRTAC Technical Presentations

- 15 Feb 92 Steenhof, K. Wintering Bald Eagle population trends in Idaho 1980-1990 and prospects for regional & national trend analysis. 13th Annual Bald Eagle Conference, Klamath Falls, Oregon.
- 11 Mar 92 Steenhof, K. Bald eagle recovery. Guest lecture for BSU 297/497: Global Environment and Health, Boise, Idaho.
- 20 May 92 Knick, S. T., J. T. Rotenberry, and T.J. Zarriello. Use of satellite imagery to assess rangelands in the Snake River Birds of Prey Area. Symposium: Ecology, Management and Restoration of Intermountain Annual Rangelands, Boise, Idaho.
- 4 Jun 92 Grothe, S. Red-tailed Hawk predation on snakes: The effects of weather on snake activity. American Herpetological and Ichthyological Society, Champaign, Illinois.
- 16 Jun 92 Van Horne, B., and G.S. Olson. Food habits, mass dynamics, and survival of *Spermophilus townsendii*, a prolonged estivator/hibernator, in shrubsteppe habitats. American Society Mammalogists Annual Meeting, Salt Lake City, Utah.
- 25 Jun 92 Rotenberry, J.T., and S.T. Knick. Evaluation of bias in on- and off-road point counts of avian abundance in shrubsteppe habitat. Cooper Ornithological Society Annual Meeting, Tacoma, Washington.
- 26 Jun 92 Grothe, S. Red-tailed Hawk predation on snakes: The effects of weather on snake activity. American Ornithologists Union, Ames, Iowa.
- 15 Sep 92 Kochert, M.N., and K. Steenhof. Nesting by raptors on an electrical transmission line. International Workshop on Avian Interactions with utility structures. Miami, Florida.
- 15 Sep 92 Engel, K.A. Controlling raven fecal contamination of transmission-line insulators. International Workshop on Avian Interactions with utility structures. Miami, Florida.
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- 13 Nov 92 Steenhof, K., and M.N. Kochert. The effect of prey and weather on golden eagle reproductive rates. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
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- 14 Nov 92 Fuller, M.R., D.H. Ellis, S.S. Klugman, and W.S. Seegar. Telemetry via satellites for raptor studies. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
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- 14 Nov 92 Schueck, L., and J.M. Marzluff. How are decisions about the influence of human activities on raptors influenced by abiotic factors? Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
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- 14 Nov 92 Marzluff, J.M., M. Vekasy, and C. Coody. Are aerial radio telemetry locations accurate and representative of prairie falcon activities? Poster paper. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
- 14 Nov 92 Seegar, W.S., W.R. Gould, M.R. Fuller, W.G. Mattox, M.A. Yates, T.L. Maechtle, J. Oar, and M. Robertson. Peregrine population dynamics in west-central Greenland. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
- 14 Nov 92 Pennycuik, C.J., M.R. Fuller, and W.S. Seegar. Ranging distances of greenland peregrines during the breeding season. Poster paper. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
- 14 Nov 92 McKinley, J.O., R.R. Townsend, L.S. Schueck, and J.M. Marzluff. How do you successfully capture and instrument specific prairie falcons (*Falco mexicanus*) in a dense nesting population? Poster paper. Annual Meeting, Raptor Research Foundation, Bellevue, Washington.
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PART II
PROGRESS REPORTS

Raptor Abundance and Reproductive Success in the Snake River Birds of Prey Area, 1992

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ANNUAL SUMMARY

In 1992, the number of prairie falcon (*Falco mexicanus*) pairs (194) in the Snake River Birds of Prey Area (SRBOPA) was higher than in 1978, 1990, and 1991, but slightly lower than 1976 and 1977. Numbers of pairs in 3 of 8 randomly selected 10-km stretches were above the long-term average. Occupancy of historical prairie falcon nesting areas was highest in canyon stretches west of the Orchard Training Area (OTA) "shadow" and lowest east of the "shadow." Reproduction inside and outside the shadow did not differ significantly. Both the number of young prairie falcons produced per nesting attempt in the SRBOPA (3.54) and the number of young per pair (3.13) were above the long-term average. Eleven falcons trapped as adults in 1991 were retrapped, sighted, or found injured in the SRBOPA. Golden Eagle (*Aquila chrysaetos*) numbers in the SRBOPA were slightly higher than in 1991 and the same as the preceding 2 years. Number of young eagles fledged per pair (0.83) was lower than the previous 2 years but higher than in 1989. As in 8 of the previous 9 years, golden eagle reproductive rates in the SRBOPA were lower than in the Comparison Area. Twenty-four of 71 historically occupied ferruginous hawk (*Buteo regalis*) nesting areas were occupied, including 10 in the Snake River Canyon, 10 on the benchlands, and 4 outside the Integration Study Area (ISA). Ten ferruginous hawk nesting areas not previously recorded were also occupied. Ninety-four occupied raptor nesting areas were found on the ISA benchlands, 30 more than in 1991. These included 17 ferruginous hawk, 9 northern harrier (*Circus cyaneus*), 44 burrowing owl (*Speotyto cunicularia*), and 24 short-eared owl (*Asio flammeus*) pairs. Relative abundance of benchland nesters inside and outside the OTA was similar. Nesting success of ferruginous hawks and northern harriers was lower inside than outside the OTA, but sample sizes were too low to test for significance. Nesting success for burrowing owls could not be evaluated because samples were biased towards successful pairs. Nesting success for short-eared owls could not be

evaluated because no successful nests were found during incubation, and young often left the nest on foot before fledging and could not be found. Multivariate analyses indicated that badger holes, percent vegetation cover, soil depth, rock outcrops, and intensity of military tracking may be related to nest site selection on the bench.

■ OBJECTIVES:

1. Assess 1992 prairie falcon abundance and long-term population trends in the Snake River Birds of Prey Area (SRBOPA), and compare 1992 falcon nesting densities inside and outside the Orchard Training Area (OTA) Shadow.
2. Assess prairie falcon reproduction at preselected nesting areas and compare estimates of productivity to long-term trends in the SRBOPA.
3. Compare prairie falcon nesting success, productivity, and fledging weights inside and outside the OTA Shadow.
4. Compare 1992 golden eagle abundance and productivity in the SRBOPA and Comparison Area.
5. Assess the relative abundance and reproductive success of benchland-nesting raptors inside and outside the OTA.
6. Compare habitat and land use characteristics of occupied benchland nesting areas to randomly selected unoccupied areas on the bench.

7. Assess ferruginous hawk occupancy and nesting success at historical nesting areas.

8. Report recoveries of banded raptors and assess preliminary information on nest site fidelity and breeding dispersal.

■ INTRODUCTION

Study 3's main objective is to determine if nesting densities and reproduction of the major raptor species in the SRBOPA have changed over time and if any such changes can be correlated with military use and fire occurrence. In addition, the best long-term approach for monitoring raptor nesting populations will be determined from this research.

The 1992 field season was the third year of the study. Field work emphasized Tasks 1, 2, and 3 of the Study 3 Plan (Kochert et al. 1991). General approaches for Tasks 2 and 3 (comparison of past and present raptor nesting densities and OTA effects) did not change or changed only slightly in 1992. Density and reproductive data were collected on golden eagles and ferruginous hawks for Task 4 (burn effects), but analyses have been deferred until accurate historical burn maps for the OTA can be developed. The

Raptor Research and Technical Assistance Center (RRTAC) is developing such maps from satellite imagery as part of the RRTAC Global Climate Change Research Project (Kramber, this volume).

In 1992, we modified the original study plan for Tasks 1, 5, and 6 (the bench survey, work on prairie falcon site fidelity, and assessment of radio transmitter effects). In 1991, we used 2 methods for sampling nesting raptors on the benchlands: line transects and variable circular plots. In 1992, we conducted a quadrat survey on the benchlands, similar to that used in 1990, but increased the size and number of quadrats surveyed, and modified the sampling technique. The site fidelity work was scaled back to include only opportunistic encounters with banded prairie falcons, and study of transmitter carry-over effects was dropped entirely. During habitat assessments, we used many of the same habitat variables used in 1991, but protocols for obtaining habitat data changed slightly in 1992.

" METHODS

Prairie Falcon Abundance and Reproduction

Abundance.--In 1992, all stretches of the Snake River Canyon and the major side canyons within the SRBOPA (Hammett to Walters Ferry) were surveyed for prairie falcon nesting activity 3 times: once between 11 March and 4 April; once between 1 May and 31 May; and once between 1 June and 25 June. As in past years, some buttes and portions of side canyons (Walters Butte, Rock Cabin Spring,

Castle Rock, Little Hole, Rattlesnake Spring, Flatiron, Cindercone, and Gill nesting areas) were excluded from the analysis.

Each month, observers surveyed standardized stretches of the canyon from observation points spaced at approximately 1-km intervals. Some side draws consisting of small or broken cliff were surveyed by walking. We avoided surveys from fixed observation points when our presence would have disturbed other target species of nesting raptors (e.g., golden eagles or ferruginous hawks). Most observation points were on the canyon floor so observers faced the potential nesting cliffs. Observations were made from the canyon rim along a few constricted stretches. Each observation point was surveyed for 2 hrs during each monthly survey, except when the survey stretch was less than 1 km. In these cases, survey time was proportionately less. Only 1 side of the canyon was surveyed from each observation point. Before field work began, 12 blocks of observation points, each containing approximately the number of points that could be surveyed by a 2-person crew in 3 days, were identified. In March the blocks were surveyed in a randomly selected order. The same order was used in the May and June surveys.

Observers recorded nesting activity of all raptors and ravens in field journals and on 1:24,000-scale U.S.G.S. topographic maps. Observations of birds wearing colored leg bands, U.S. Fish and Wildlife Service leg bands, or other markers were also recorded. We plotted nests and reproductive activity on black and white 1:24,000-scale aerial photographs. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

Results were analyzed for the entire SRBOPA and for 10-km stretches of the canyon delineated in U.S. Dep. Inter. (1979). Data were compared with years when surveys of the entire area were complete (1976, 1977, 1978, 1990, and 1991) and for certain 10-km stretches surveyed between 1976 and 1991. Nesting densities in each 10-km unit were analyzed in relation to the amount of available cliff area [as calculated by Bentley and Hardyman (1978) and presented in U.S. Dep. Inter. (1979)].

In 1992, the OTA "Shadow" (previously defined as 10-km Units 7, 8, and 9) was extended west to include 10-km unit 6, based on 1991 radio-telemetry results. In 1991, several radioed birds from 10-km Unit 6 spent considerable amounts of time (30-40% of their fixes) inside the OTA (Marzluff et al. 1991). Densities in the OTA Shadow (Units 6, 7, 8, and 9) were compared with stretches southwest and southeast of the OTA.

Reproduction.--Prairie falcon nesting success and productivity in the SRBOPA were assessed for 2 treatment groups in 1992. Study 2 assessed reproduction at nesting areas where they radioed adults in 1992, and Study 3 assessed reproduction at a randomly selected sample of "control" nesting areas; i.e., those not radioed in 1992.

Before the nesting season, all historical nesting areas in the Integration Study Area (ISA) were stratified as east, west, or inside the OTA shadow, and nesting areas were randomly assigned to Study 2 and Study 3. The order of random selection determined which nesting areas would be studied and which would be back-up sites. As in 1991, the target "control" sample size (based on power tests; Kochert et al. 1991) was 51

"control" nesting areas. However, because the OTA shadow configuration changed in 1992, the target sample sizes inside and outside the OTA Shadow also changed. In 1992, target ISA sample sizes were 12 nesting areas from 10-km units west of the OTA Shadow, 23 from units inside the OTA Shadow, and 16 from units east of the OTA Shadow. In 1992, 10 nesting areas were also selected east of the ISA boundary to monitor reproductive success throughout the SRBOPA. Nesting areas east of the ISA boundary were not used in the analysis of OTA effects.

As in 1992, we began monitoring selected "control" nesting areas in early March (prior to incubation), and continued observations up to the time of fledging. All selected nesting areas were checked during each of the 3 density surveys. If occupancy was not determined during the March survey, replacement nesting areas were selected from the list of backups in the original random order. We continued observations at the replaced nesting areas until we were certain they were unoccupied, usually after 6-8 hrs of observation.

Between early April and late May, nesting areas were observed from remote observation points to identify probable nesting scrapes. Each observation bout continued for up to 2 hrs. Criteria for confirming scrape locations and thereby identifying probable breeding attempts included: observation of eggs in a scrape or nest; an adult observed in incubating posture; or observations of an adult falcon entering a scrape and remaining within the scrape for 1 hr or more. If scrape locations could not be identified during scheduled observation bouts, we climbed to locate scrapes. We continued observations at

nesting areas where scrapes could not be identified to determine if nonbreeding pairs were present.

Nesting attempts were considered successful if 1 or more young reached 30 days of age (Steenhof 1987). Nestlings were aged at most nests by remote observations late in the brood-rearing period using an aging key (Moritsch 1983). Some nests were climbed to age young. Nest climbs to count fledging-aged young were scheduled so visits occurred when young were 30-35 days old. During nest climbs, young were weighed, examined for condition, and banded with a USFWS band on the right leg and a black anodized aluminum band with a unique alphanumeric code on the left leg. We also measured foot pad length, tarsal width, and length of the seventh primary. To control for observer bias, measurements were taken by only 3 people. In addition, we exchanged personnel with Study 2 so that 24% of control broods were measured by Study 2 personnel and 29% of broods with radioed adults were measured by Study 3 personnel. Weights were adjusted on all birds whose crops were more than 25% full by subtracting estimated crop weights (BLM, unpubl. data). Birds with foot pads > 86 mm were considered females, and those with foot pads < 86 mm were called males.

To compare productivity among years, we used only 1992 "control" nesting areas and excluded nesting areas from previous years where experimental disturbances, nest site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment occurred. This ensured that results were not biased by researcher manipulations. Analyses of percent of pairs successful were based on pairs selected for study prior to each nesting season. To assess the percent

of nesting attempts successful, only those breeding attempts confirmed during incubation and for which outcome was known were included in the analysis. Number of young fledged per successful attempt was based on all pairs for which complete fledge counts were obtained. Number fledged per pair and per attempt were estimated as the products of percent success and number fledged per successful attempt.

Golden Eagle Abundance and Reproduction

In 1992, 39 traditional golden eagle nesting areas in the SRBOPA and 23 nesting areas in the Comparison Area (see Kochert et al. 1991) were preselected for observation. All 62 nesting areas were surveyed by helicopter or from the ground in conjunction with other raptor surveys.

Helicopter surveys were conducted from a Bell 206 Jet Ranger on 16 March and 27 May. The purpose of the first survey was to determine if nesting areas were occupied and if eggs had been laid. Nesting areas with breeding pairs were re-checked during the second flight to assess productivity. Helicopter surveys were conducted along the Snake River from Givens Hot Springs east to Glenns Ferry, and along the Pacific Power and Light (PP&L) transmission line from Miles 45 to 133. Helicopters were flown at speeds of 70-95 km/hr, and we hovered approximately 10 m from nests for 5-25 sec to view nest contents. No attempt was made to flush incubating birds or count eggs.

Nesting areas where occupancy or breeding status could not be ascertained during helicopter flights were subsequently surveyed from the ground. Ground surveys

in 1992 were conducted in conjunction with prairie falcon density surveys in the SRBOPA and as independent efforts. Some nests in the Comparison Area were surveyed from the ground by Idaho Power Company personnel.

Eagle pairs that showed no evidence of egg-laying after repeated observations were categorized as "nonbreeding." A "breeding attempt" was confirmed if an occupied nesting area contained an incubating adult, eggs, young, or any indication that eggs had been laid (e.g., fresh eggshell fragments in fresh nesting material). A breeding attempt was "successful" if 1 or more young reached 51 days of age (Steenhof 1987). A photographic aging key was used to age young (Hoechlin 1976). Eagle nests checked after young had fledged were considered successful if: 1) a platform decorated this season was worn flat and contained fresh prey remains; 2) fresh fecal matter covered the back and extended over the edge of the nest; and 3) no dead young birds were found within a 50-m radius of the nest.

Percent of pairs breeding in 1992 and earlier years was calculated from preselected pairs (Steenhof and Kochert 1982). Percent of nesting attempts that were successful was based on attempts confirmed during incubation. Nesting areas where researcher manipulations (experimental disturbances, nest-site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment) had occurred were excluded from analyses of percent success.

Ferruginous Hawk Occupancy and Reproduction

In 1992, all 71 historically occupied ferruginous hawk nesting areas in the

SRBOPA were preselected for observation. All nesting areas were classified as ISA or non-ISA areas. In the ISA, nesting areas were classified as canyon or benchland areas.

Twenty-eight canyon nesting areas were observed during the March, May, and June prairie falcon density surveys (see above). Twenty-nine benchland nesting areas were surveyed at least 3 times between 20 March and 10 July (see below). Fourteen historical nesting areas outside the ISA were surveyed at least twice between the 21 March to 13 May egg laying period (based on SRBOPA nesting records). Occupied historical nesting areas were revisited until success was determined. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

In addition to ground surveys, a helicopter survey was conducted on 27 May, in conjunction with the golden eagle survey. The survey included all nesting areas on the PP&L transmission line within the SRBOPA as well as any occupied nesting areas in the canyon and outside the ISA where breeding status was previously undetermined. Ferruginous hawk nesting areas found for the first time in 1992 were also revisited as necessary to determine breeding status and success. To report success rates we used all nesting areas confirmed during incubation (where eggs or an incubating adult was seen) and where fate was known. Nesting attempts were considered successful if 1 or more young reached 31 days. Nestlings were aged using a photographic aging key (Moritsch 1985).

Nesting of Raptors on the Benchlands

Relative Abundance.--To assess the relative abundance of raptors nesting on the benchlands north of the canyon, we searched randomly selected quadrats inside and outside the OTA to locate occupied nesting areas. We used a modification of the quadrat surveys used in 1990 (Lehman et al. 1990), but increased the size of quadrats and allowed greater latitude in the sampling effort. Target species included the ferruginous hawk, northern harrier, burrowing owl, and short-eared owl.

The goal of quadrat surveys was to locate as many nesting areas within the sampling units as possible. Surveys were conducted within 9-km² quadrats (3 km/side). Surveys of test quadrats in late February 1992 indicated a single field technician could adequately cover a quadrat of this size by vehicle and on foot in a single day. The target sample size was 50 quadrats (14 inside the OTA and 36 outside the OTA). The minimum acceptable sample size was 40 quadrats.

To select quadrats, we superimposed a 9-km² cell grid on the ISA using the Geographic Information System (GIS). Cells falling on the ISA or OTA boundaries, within 250 m of the canyon rim, or within the Artillery Impact Area were rejected. We then randomly selected 50 cells as survey quadrats from those remaining on the grid. Quadrat boundaries were drawn on U.S. Geological Survey 1:24,000-scale topographic maps and orthophoto quadrangles. For quadrats outside the OTA, we examined the orthophoto quadrangles and black and white 1:24,000-scale 1987 aerial photographs to assess amounts of agricultural development (irrigated or dry

cropland and irrigated pasture) within each quadrat. Those with 10% or more of their surface areas developed were rejected. We selected new quadrats as needed to assure a minimum sample size of 40 quadrats. The extent of agricultural development in each selected quadrat was verified on the ground during the first field survey.

We sampled each quadrat twice during the nesting period. At least 1 survey began at dawn or ended at dusk. Surveys were scheduled to include the egg laying period for all 4 target species and were conducted from 20 March to 11 April and 15 April to 14 May. We tried to send different observers to each quadrat during the 2 surveys. Follow-up surveys of occupied nesting areas were scheduled according to estimated ages of nestlings, or if age estimates were not available, prior to the earliest known fledging date of each target species.

All quadrats had a north-south orientation, but we did not mark quadrat boundaries in the field. We used maps and compasses and focused on geographic features to remain inside quadrats. We drove all roads within each quadrat, pausing occasionally to scan for raptors. Areas within sampling units not visible from roads were walked. We did not follow a particular pattern during walking surveys, but tried to visually scan all areas not covered while driving. To ensure uniform coverage throughout each quadrat, we developed a strategy for searching before each quadrat survey. Most quadrats were surveyed by 1 observer, but some were surveyed by 2. Observers judged when a quadrat had been adequately surveyed. The maximum survey period was 8 hrs, but there was no minimum survey period.

During quadrat surveys, we noted the behavior of all raptors observed. A nesting area was considered occupied if territorial defense, courtship, or other reproductive-related activity was observed (see U.S. Dep. Inter. 1992). Evidence for a breeding attempt included the presence of eggs, young, or any field sign indicating that eggs were laid (e.g., adults in incubating posture, eggshell fragments in fresh nesting material--U.S. Dep. Inter. 1992). We tried to assess fate at all nesting areas where breeding attempts were confirmed using protocols described below for historical nesting areas.

When we suspected nesting activity within a quadrat, observers immediately conducted a short search to locate the nest. If nests could not be located within 0.5 hr, the survey resumed. We visited these areas later to locate nests. Follow-up visits were scheduled before the \bar{x} hatching date for each species (criteria for nesting chronologies are given below). When nests were found, observers plotted the locations on field maps using aerial photographs and orthophoto quadrangles. To ensure that nests could be found during follow-up surveys, observers flagged a nearby shrub or a stake in shrubless areas no closer than 10 m from a nest, and recorded directions to a nest. When possible, the same observer who found a nest returned for follow-up surveys. Coordinates of nests, or the centroids of nesting areas where nests were not found, were established using the Global Positioning System (GPS) during habitat surveys (described below) in July and August.

To assess differences in relative abundance inside and outside the OTA, we classified quadrats based on whether or not occupied nesting areas (all species pooled) were

found. Groups were compared inside and outside the OTA using a contingency table analysis. The StatXact statistical package (Cytel 1989) was used to calculate exact p-values.

Historical Nesting Areas--We surveyed 116 of 118 raptor nesting areas on the ISA benchlands known to be occupied at least once in previous years. Twelve nesting areas were visited only 1 or 2 times. Of the remaining areas, 52 were visited 3 times, and 52 were visited 4 or more times. We did not consider a historical nesting area to be vacant unless it was checked at least 3 times during the nesting period, and had at least 3 hrs of observation. Visits were scheduled according to the nesting chronologies of the 4 target species. Chronologies of ferruginous hawks, burrowing owls, and northern harriers were based on SRBOPA nesting records; dates for short-eared owls were based on Linner (1980). Initial visits at all nesting areas occurred between 22 March and 25 April.

During our first visit to a historical nesting area, we checked each known nest within the area. In some cases, we also checked other potential nesting substrates visible from historical nests. If nesting attempts were confirmed during initial visits, nesting areas were revisited just before fledging to determine success. We revisited all occupied nesting areas where nesting attempts were not confirmed when they were found. Ferruginous hawk breeding attempts were considered successful if 1 or more young reached 31 days of age, and burrowing owl breeding attempts were considered successful if 1 or more young reached 28 days of age. We used photographic aging keys (Moritsch 1985, and D. Beig, Boise State Univ., unpubl. data) to

age nestlings of both species. Short-eared owl and northern harrier nesting attempts were considered successful if 1 or more young reached 20 and 24 days, respectively (Clark 1975, Steenhof 1987). We used descriptions of feather development to age nestlings of both species. For northern harriers, nestling ages were based on Bent (1961) and Watson (1977). For short-eared owls, nestling ages were based on Karalus and Eckert (1987) and Johnsgard (1988). Nest visits to confirm success continued through 15 July.

Other Nesting Areas.--To locate nesting areas not recorded previously, we followed up all observations of reproductive-related activity involving any of the 4 target species reported by other study teams or Study 3 personnel. If nesting activity was observed by Study 3 personnel while traveling in the ISA, observers conducted an immediate search of the area for evidence of a nesting attempt. We asked other study teams involved in BLM/IDARNG research to record observations on a standard data form. All nesting areas where breeding was confirmed were revisited later in the nesting season to determine nesting success. Visits were scheduled according to the nesting chronologies of the 4 target species, as cited above for historical nesting areas, using similar protocols.

Nesting Success.--To assess reproductive success of nesting raptors on the benchlands, we tried to assess fate at all historically occupied nesting areas, nesting areas found during quadrat surveys, and nesting areas found opportunistically by Study 3 and other study teams. To avoid biasing samples towards successful nests, we analyzed only those ferruginous hawk, northern harrier, and short-eared owl nesting attempts found

during incubation (where adults in incubating position or eggs were observed). We determined if successful burrowing owl pairs were found during incubation by backdating from age estimates of young obtained after young had emerged from their burrows, using an incubation period of 30 days (Henny and Blus 1981) and a photographic aging key (D. Beig, Boise State Univ., unpubl. data). We could not determine if unsuccessful pairs were found during incubation, so we included all unsuccessful pairs found before 3 May, the earliest known hatch date in the SRBOPA in 1992.

Habitat Assessments.--Habitat assessments in the ISA had 4 objectives: (1) to identify habitat characteristics associated with nest site selection; (2) to identify habitat characteristics associated with nesting success; (3) to assess the relative availability of important habitat features inside and outside the OTA; and (4) to determine if nest distribution is related to military use.

We used canonical discriminant analysis and logistic regression to identify features associated with nest site selection on the benchlands. Habitat characteristics were described at 92 occupied nesting areas and 82 random points. Habitat characteristics were not described at 2 ferruginous hawk nesting areas. One nesting area was in a plowed field on private land. The landowner cut down the nest tree early in the breeding period. The second nesting area was found after habitat surveys ended.

Discriminant analyses were done for each species and for all species pooled. We also used log-likelihood contingency table analyses to assess differences in categorical habitat variables between nests and random

points. Habitat characteristics at random points inside and outside the OTA were compared using t-tests. Habitat at occupied nesting areas was assessed by Study 3 field crews during a final visit after fledging. These visits continued through 29 August. Habitat at random points was assessed by Study 5 field crews between 6 May and 6 August.

Habitat variables estimated ocularly by Study 3 field personnel within 50-m and 100-m radii of nests and random points included number of rock outcrops, vegetative cover classes, presence of hills and buttes (with slopes > 15%), presence of agricultural development, artificial perches, artificial nest structures, and roads. We also assessed the presence of agricultural development (defined as any irrigated or dry cropland, including irrigated pasture) and described vegetative cover types within a 500-m radius of the nest and random point. Slope of hills and buttes was measured with a clinometer. Vegetative cover classes were described as "open" or "closed." Open cover types had low vegetation (e.g., grasses) or lacked vegetative cover on 50% or more of the prescribed radius. Closed cover types had shrubs on 50% or more of the prescribed radius.

Habitat characteristics obtained from the Digitized Resource Data Base Map (DRDBM) included grazing regime type, soil depth, soil development, and landform. Grazing regimes were either spring-fall range (north of the drift fence) or winter range (south of the drift fence). Soils data were obtained from Ada, Canyon, Elmore, and Owhyee County soil surveys (U.S. Dep. Agric. 1972, 1980, 1991, unpubl.). Soil depth was analyzed for 3 categories: shallow < 51 cm, medium (51-102 cm), and deep

(> 102 cm). Landform was classed as "basaltic" or "other soil type," and soil development was considered either "strong" or "weak." We also calculated the proportion of each military regime within a 1-km radius of each nest or random point. Military regime types were defined as: (1) artillery position areas; (2) tracking areas; (3) inside the Impact Area; and (4) non-military (outside the OTA). In the analysis, we combined tracking areas and artillery position areas into 1 category.

Habitat variables obtained during transect surveys at nesting areas and random points included percent vegetative cover, percent shrub cover, \bar{x} shrub height (in cm), species richness (number of plant species), plant species diversity index ($1/\sum p_i^2$ where p_i was the proportion of the i th species in the sample), number of badger burrows, military vehicle tracking intensity, and cow sign. At random points, habitat characteristics were sampled along a single 5 x 400-m strip transect and 7 50-m transects perpendicular to the 400-m center line. At nesting areas, habitat characteristics were sampled along 2 5 x 200-m perpendicular transects bisected by the nest or centroid of a nesting area where the nest was not found, and along 8 50-m transects perpendicular to the 200-m center lines (4 per 200-m transect). Percent cover, species richness, and the diversity index were estimated from point frames along the 50-m lateral transects. Numbers of badger burrows, cow sign (presence of cow dung), and tracking intensity were estimated ocularly along the transect center lines. Tracking intensity and cow sign indexes were the number of 4 100-m transect subsections with tank tracks or cow sign. Field procedures used to obtain these data were described by Knick (1991).

Nest Distribution in the OTA--To determine if nest distribution was related to military use, we analyzed 4 variables obtained from the DRDBM for nests and random points in the OTA. These included distance from the nest or random point to the nearest firing point, nearest firing fan, and the Multi-Purpose Range Complex. We also determined the military sector in which the nest or random point fell. These analyses were done with G-tests and t-tests.

RESULTS

Prairie Falcon Abundance and Reproduction

Abundance.--We identified 194 prairie falcon pairs in the SRBOPA in 1992, the highest count since 1977. The number of occupied prairie falcon nesting areas was still slightly lower than 1976 and 1977 levels when 205 and 206 pairs were found.

Table 1. Number of prairie falcon pairs by 10-km unit, 1990-92.

10-km Unit	1990	1991	1992	Change from 1991	Change from 1976-78 ^a
03	1	1	1	0	0
04	20	20	23	+	0
05	41	48	41	-	0
06	32	31	32	+	0
07	15	14	13	-	0
08	13	6	12	+	0
09	5	6	7	+	0
10	2	3	2	-	0
11	1	2	1	-	-
12	15	12	17	+	0
13	19	19	19	0	0
15	10	8	10	+	-
16	1	1	1	0	-
24	3	6	7	+	+
25	2	1	2	+	0
26	3	3	3	0	0
37	2	2	2	0	0
35	0	0	1	+	+
TOTAL	185	183	194	+	0

^a 0 = within the 1976-78 range

- = lower than the 1976-78 range

+ = higher than the 1976-78 range

Numbers of pairs increased from 1991 levels in 9 10-km stretches, decreased in 4, and remained the same in 5 others (Table 1).

The notable changes recorded in 1991 seemed to have reversed in 1992. Numbers of pairs in Unit 8 (the Black Butte area) doubled from 1991 and returned to near-1990 levels. Numbers in Unit 5 decreased to 1990 levels, after a substantial increase in 1991. Only 3 10-km units (11, 15, and 16) had prairie falcon densities below levels

recorded from 1976-78. Two stretches (24 and 35) had more pairs than observed between 1976 and 1978. We counted more pairs (80) in the 8 randomly selected stretches than in any year since 1977 (Table 2). In units 7, 8, and 15 (the 3 stretches surveyed annually from 1976 through 1984 and every other year thereafter), 1992 prairie falcon densities increased by 7 to 35 pairs, just below the long-term average of 35.8 pairs for the 3 units (Fig. 1).

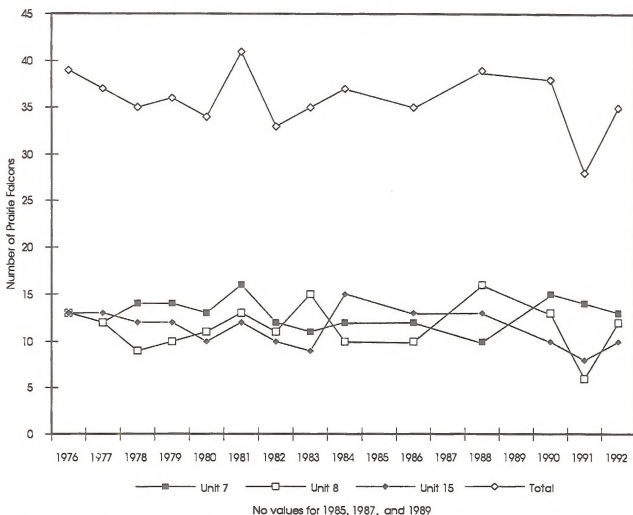


Fig. 1. Number of occupied prairie falcon nesting areas in 10-km survey units 7, 8, and 15 in the SRBOPA.

Table 2. Number of occupied prairie falcon nesting areas in randomly selected 10-km units in the SRBOPA.

10-Km Unit	1976	1977	1978	1986	1988	1990	1991	1992	\bar{x}
3	0	0	1	0	1	1	1	1	0.6
6	32	32	30	23 ^a	28	32	31	32	30.0
7	13	12	14	12	10	15	14	13	12.9
8	13	12	9	10	16	13	6	12	11.4
15	13	13	12	13	13	10	8	10	11.5
24	3	4	2	2	4	3	6	7	3.9
26	4	5	3	1	4	3	3	3	3.3
37	3	3	2	3	2	2	2	2	2.4
Total	81	81	73	64	78	79	71	80	76.0

^a Surveys of the south side of the river between the mouth of Sinker Creek and Balls Line West may have been incomplete in 1986.

The number of falcon pairs per km of canyon was still highest west of the OTA (3.20 pairs/km in units 4 and 5) and lowest east of the OTA (1.23 pairs/km in units 11, 12, and 13). The 40-km OTA shadow (units 6, 7, 8, and 9) had intermediate densities, with 1.63 pairs/km. The difference in densities was not as great when viewed in relation to the area of cliff in each stretch. The number of pairs per km² of cliff was still lowest east of the OTA (0.032), but densities in the OTA shadow (0.042) were similar to those west of the shadow (0.041).

Reproduction.--Of 108 preselected and back-up nesting areas monitored by Study 3 during the 1992 nesting season, 63 (58%) were occupied by prairie falcon nesting pairs. Occupancy rates were highest west of the OTA where 14 of 20 historical nesting areas (70%) were occupied. In the OTA shadow, 23 of 38 preselected nesting areas (61%) were occupied, and 17 of 28 ISA nesting areas east of the OTA were occupied (61%). East of the ISA, occupancy rates were even lower: only 9 of 22 nesting areas (41%) east of the ISA were occupied.

Control pairs had a 75% nesting success rate, lower than in 1991, but above the long-term average (Table 3). Forty-two pairs bred successfully, 6 breeding pairs were unsuccessful, and breeding was not confirmed for 8 of the unsuccessful pairs. Successful control pairs fledged an average of 4.17 young, yielding an estimated 3.13 young fledged per pair (Table 3).

Breeding attempts were confirmed during incubation at 34 of the 63 control nesting areas, and 29 of these pairs (85%) were successful (Table 3). Number of young

fledged per attempt was 3.54, still above the 19-year average rate of 2.85 (Table 3). Because the success rate of control nesting attempts (85%) did not differ significantly ($G_1 = 0.01$, $P = 0.92$) from that of breeding pairs radioed in 1992 (86%), both groups were pooled in subsequent analyses of 1992 reproduction by region. Nest success per attempt in the OTA shadow (85%) was lower than that east and west of the shadow (90%), but differences were not statistically significant ($G_1 = 0.31$, $P = 0.70$). Success rates east of the shadow (91%, $n = 11$) were similar to those west of the shadow (89%, $n = 19$). Mean number of young fledged per successful pair did not differ significantly among the east ($\bar{x} = 4.11$), west ($\bar{x} = 4.47$), and shadow ($\bar{x} = 4.29$) areas (ANOVA, $F_{2,42} = 0.42$, $P = 0.66$).

Female fledging weights averaged 783 g ($n = 49$; SD = 73) inside the shadow and 824 g ($n = 53$; SD = 54) east and west of the shadow, and male weights averaged 542 g ($n = 36$; SD = 51) inside the shadow and 561 g ($n = 48$; SD = 25) outside the shadow. Simple analyses for variance suggested both these differences were significant (P 's < 0.05), but analyses of variance using length of seventh primary as a covariate found significant differences only for females ($P < 0.001$ for females; $P = 0.067$ for males). Seventh primary length was significantly related to weight in both sexes (P 's < 0.001). Birds measured by Study 2 had significantly smaller seventh primaries ($t = 3.74$, $P < 0.0001$ for males; $t = 3.26$, $P = 0.002$ for females) than those measured by Study 3. Study 2 birds comprised a slightly higher proportion of the OTA shadow sample (49%) than of the birds sampled east and west of the OTA (45%).

Table 3. Nesting success and productivity of prairie falcons in the SRBOPA, 1974-92. Sample sizes are in parentheses.

Year	% of Pairs Successful	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Attempt ^a	# Fledged/ Pair ^b
1974	73% (15)	64% (11)	3.94 (17)	2.52	2.88
1975	83% (23)	86% (21)	3.74 (27)	3.21	3.10
1976	74% (23)	79% (29)	4.00 (41)	3.16	2.96
1977	57% (14)	67% (27)	4.08 (25)	2.73	2.33
1978	45% (20)	18% (17)	3.29 (17)	0.59	1.48
1979	70% (40)	75% (32)	3.73 (30)	2.80	2.61
1980	59% (49)	65% (54)	4.03 (36)	2.62	2.38
1981	80% (51)	83% (46)	4.04 (22)	3.35	3.23
1982	46% (26)	69% (26)	3.53 (17)	2.44	1.62
1983	71% (31)	73% (26)	3.24 (17)	2.36	2.30
1984	---	88% (16)	3.95 (19)	3.48	---
1985	---	93% (14)	4.08 (13)	3.79	---
1986	---	44% (18)	3.43 (7)	1.51	---
1987	---	72% (36)	4.32 (31)	3.11	---
1988	---	78% (9)	3.86 (7)	3.01	---
1989	---	83% (6)	3.67 (6)	3.05	---
1990	---	74% (19)	4.06 (18)	3.00	---
1991	81% (42)	94% (16)	4.08 (24)	3.84	3.11
1992	75% (56)	85% (34)	4.17 (30)	3.54	3.13
\bar{x} All Years	68% SD = 13%	73% SD = 18%	3.86 SD = 0.30	2.85 SD = 0.78	2.59 SD = 0.59

^a Calculated as the product of % attempts successful and # fledged/successful attempt.^b Calculated as the product of % of pairs successful and # fledged/successful attempt. Data are not available for 1984-90 because prairie falcon pairs were not preselected in those years.

Dispersal and Nest Site Fidelity.--Eleven prairie falcons radioed as breeding adults in 1991 were encountered in 1992 (Table 4). Two falcons (CSJ and Priest Rapids II) were trapped on their 1991 nesting areas, and the radioed male from the 1991 Beercase Draw nesting area was found injured on 11 March 1992, 4 km from Beercase Draw. The Beercase bird was turned over to a

veterinarian, but soon died of an infection. Eight falcons may have occupied the same nesting area as in 1991 ($n = 6$) or an adjacent nesting area ($n = 2$). These birds were wearing 1991 radios, but leg bands were not read so they were not individually identified. Six of the 8 birds observed appeared to be the same sex radioed in each area in 1991.

Table 4. Encounters with prairie falcons radioed as breeding adults in 1991.

1991 Nesting Area	Band Number	Sex	Status	1992 Status of 1991 Nesting Area
Beercase Draw	816-70255	♂	Found injured 4 km upstream	Successful-♀ unmarked, ♂ radioed in 1992
Bitch	(816-70262?)	♂	Possible sighting on nesting area	Unknown success-1 adult not identified, 1 adult radioed in 1991
Cabin	(1807-01229?)	♀	Possible sighting on nesting area	Occupied-♂ not identified, ♀ radioed in 1991
CSJ	816-74715	♂	Trapped on nesting area wearing radio	Occupied-♀ not identified, ♂ radio removed
Fang	(1807-01234?)	♀	Possible sighting at adjacent nesting area	Vacant
Fawn Humpback	(816-70250?)	♂	Possible sighting on nesting area	Successful-♀ not identified, ♂ radioed in 1991
Powerline Mirror	(816-70251?)	♂	Possible sighting at adjacent nesting	Occupied, unsuccessful- adults not identified area
Priest Rapids II	816-70149	♂ ^a	Trapped on nesting area w/o radio	Successful-♀ not identified, ♂ radioed again
Swan I Draw	(1807-01225?)	♀	Possible sighting on nesting area	Successful-♂ not identified, ♀ radioed in 1991
Tom Butte West	(1807-01232?)	♀	Possible sighting on nesting area	Successful-♂ not identified, ♀ radioed in 1991
Wildhorse Butte NE	(1807-01231?)	♀	Possible sighting on nesting area	Successful- 1 adult not identified, 1 radioed in 1991

^a 1991 radio worn only 8-9 March 1992.

In addition to the 1991 radioed falcons, researchers captured or observed marked adults at 5 other nesting areas in 1992 (Table 5). Three color-banded prairie falcons marked as nestlings were observed as adults at the Swan I Draw Mouth, Tom Draw, and Sinker Butte Pump nesting areas in 1992. The Swan I Draw Mouth and Tom

Draw falcons were 1.2 km and 4.8 km from their respective 1990 natal areas. The alphanumeric code on the Sinker Butte Pump falcon was not read, but a black band on the left leg indicated it was probably marked as a nestling in 1990 or 1991. Two prairie falcons captured by Study 2 were first time recaptures.

Table 5. Band sightings and recoveries of prairie falcons banded in the ISA reported in 1992.^a

Natal Nesting Area and Year	Band Number	Sex	Status	Location Reported
Balls Pt Upstream, 1987	816-70165	♂	Trapped & radioed 17 Mar 92, 8.3 km away	Peregrine Cliff
Fever Basin Upstream, 1990	816-74734	♂	Sighted 1 Jun 92, 1.2 km away	Swan I Draw Mouth
Shoofly, 1990	816-74716	♂	Trapped & radioed, 31 Mar 92, 13 km away	Thirst Draw DS
Tick II, 1990	816-74725	♂	Sighted 21 May 92, 4.8 km away	Tom Draw
Unknown, 1990 or 1991	Unknown	U	Sighted 18 Jun 92	Sinker Butte Pump
Sun Goddess, 1987	987-53098	U	Found USFWS band, 19 May 92, 0.3 km away	Sun Goddess Draw
Cattleguard Gate, 1991	816-70275	U	Found dead 28 Feb 92, ~ 488 km away	Medical Lake, WA
Swan Dam Road South Side, 1990	987-53150	♀	Trapped & released 10 Nov 90, ^b ~ 320 km away	Blackfoot, ID

^a These recoveries are in addition to those in Table 4.

^b This is a 1990 recovery not reported until 1992.

The Peregrine Cliff male, banded as a nestling in 1987, was recaptured 8.3 km from his natal area. The Thirst Draw DS male, banded as a nestling in 1990, was 13.0 km from his natal area. The Priest Rapids II and CSJ falcons captured by Study 2 on the same nesting areas used in 1991 were also marked as nestlings in 1987 and 1990, respectively. These birds were captured 4.6 km (Priest Rapids II) and 14.2 km (CSJ) from their natal areas. The CSJ male's radio was removed when it was recaptured on 25 March 1992. The Priest Rapids II male had worn its 1991 radio for only 2 days and was radioed again this year. We also received 3 recoveries of banded prairie falcons, 2 of which were outside the SRBOPA. A nestling banded in 1991 at Cattleguard Gate was found dead near Medical Lake, Washington on 28 February 1992, approximately 488 km from its natal area. A nestling banded in 1990 at Swan Dam Road South Side was trapped and released near Blackfoot, Idaho on 10 November 1990, approximately 320 km from its natal area. In May 1992, a Study 2 researcher found a band from a 1987 Sungoddess nestling 300 m from the Sungoddess nesting area. The bird probably never left its natal area.

Golden Eagle Abundance and Reproduction

Abundance.--In 1992, golden eagle pairs occupied 29 (76%) of the 38 preselected nesting areas in the SRBOPA. In addition, golden eagles began nesting on a transmission tower (PP&L 102) where eagles have not nested previously. With this new pair, the number of occupied nesting areas was 1 more than in 1991 and the same as in 1989 and 1990 (Table 6). However, the number of occupied nesting areas was 5 less than in 1973, 1974, and 1976. A linear regression: $y = 52.7 - 0.26 \text{ years}$

showed that the number of eagle pairs had declined significantly ($r^2 = 0.52$, $P < 0.001$) from 1971-92.

Eagle pairs occupied 21 (91%) of the 23 preselected nesting areas in the Comparison Area in 1992. Of the 12 vacant nesting areas in the SRBOPA and Comparison Area, 6 have not been occupied since 1982 or earlier. Of these, 3 (Bruneau Flats, Malad, and Simpkin) have not been occupied since 1978 or earlier. Two vacant nesting areas (Strike II and Swan Dam) were vacant for the fourth consecutive year, and eagles have used the nesting area associated with the PP&L 125 tower only once (in 1988). Two vacant nesting areas (Pump Station and Grand View Feedlot) appear to have been absorbed by adjacent pairs. Observations by Study 2 in 1991 indicated that the pair from the "Beercase" nesting area regularly used the "Feedlot" territory so it appears that 1 pair has absorbed both nesting areas (and may have done so as early as 1989). A similar situation may have occurred at the Pump Station/ Delates Delight nesting areas because only 1 of the 2 adjacent nesting areas has been occupied in each year since 1977. The A-334 nesting area was vacant for the first time since surveys began in 1966. However, eagles successfully nested in the Pilgrim nesting area approximately 1.6 km from the A-334 nesting area. This was the first nesting attempt in the Pilgrim nesting area since 1971, and we suspect that the A-334 pair nested in this territory in 1992.

Reproduction.--Golden eagle reproduction in the SRBOPA was lower than in 1991, but higher than from 1984-1989 (Table 6). Percent of pairs breeding decreased from 90% in 1991 to 86% in 1992, and percent of breeding attempts successful decreased from 73% to 56% between those years. The

Table 6. Nesting success and productivity of golden eagles in the SRBOPA, 1971-92. Sample sizes are in parentheses.

Year	# Occupied Nesting Areas	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Pair ^a	Total Fledged
1971	34	100% (31)	60% (20)	1.89 (19)	1.13	39
1972	34	-----	-----	1.64 (11)	-----	---
1973	35	65% (34)	44% (18)	1.37 (8)	0.39	14
1974	35	73% (30)	56% (18)	1.42 (12)	0.58	20
1975	33	75% (32)	56% (18)	1.43 (14)	0.60	20
1976	35	70% (33)	47% (15)	1.62 (13)	0.53	19
1977	34	82% (33)	59% (17)	1.53 (15)	0.74	25
1978	32	80% (30)	70% (10)	1.71 (17)	0.96	31
1979	30	97% (30)	61% (23)	1.53 (19)	0.91	27
1980	31	87% (31)	72% (18)	1.77 (22)	1.11	34
1981	30	100% (30)	74% (23)	1.73 (22)	1.28	38
1982	30	87% (30)	80% (25)	1.95 (19)	1.36	41
1983	28	96% (27)	72% (18)	1.56 (16)	1.07	30
1984	31	-----	61% (18)	1.55 (11)	0.60 ^b	19
1985	32	39% (31)	42% (12)	1.00 (4)	0.16	5
1986	29	54% (28)	29% (14)	1.33 (6)	0.21	6
1987	32	78% (32)	32% (25)	1.38 (8)	0.34	11
1988	32	74% (31)	55% (22)	1.54 (13)	0.63	20
1989	30	80% (30)	63% (19)	1.36 (14)	0.69	21
1990	30	87% (30)	80% (25)	1.65 (20)	1.15	33
1991	29	90% (29)	73% (22)	1.58 (19)	1.04	30
1992	30	86% (29)	56% (16)	1.73 (19)	0.83	25

^a Based on % of pairs breeding, % of attempts successful, and # fledged/successful attempt.^b Based on % of pairs successful and # fledged/successful attempt.

number of young fledged per successful nesting attempt increased from 1.58 to 1.73, and number of young fledged per pair decreased from 1.04 to 0.83 between 1991 and 1992. At least 3 eagle pairs (1 in the SRBOPA, 1 in the Comparison Area, and 1 on the eastern end of the PP&L transmission line) produced 3 fledging-aged chicks in 1992.

As in 8 of the previous 9 years, golden eagle reproductive rates in the SRBOPA were lower than in the Comparison Area (Table 7). Percent of pairs breeding and percent of breeding attempts successful were slightly but not significantly lower (G_1 -tests, P 's > 0.10) in the SRBOPA than in the Comparison Area (Table 7). However, number of young fledged per successful attempt was slightly higher in the SRBOPA.

Dispersal and Nest Site Fidelity.--A male golden eagle, trapped by Study 2 in 1991 at PP&L 119 bred at this nesting area again in 1992. In 1992, this bird was 15 years old and nested 42.6 km from its natal area. Study 3 personnel observed an adult golden eagle with a yellow-blue right wing marker on tower 69/4 of the PP&L transmission line on 27 May. This bird was assumed to be associated with the nest on PP&L 68/3. The marker color and position indicates the bird was banded as a nestling in the Snake River Canyon in 1980 or earlier. A bird with the same marker was observed breeding at PP&L 68/3 in 1989. Study 2 personnel reported an adult golden eagle wearing what appeared to be a yellow right wing marker on 4 February, hunting 3.2 km north of Oreana, Idaho. If the marker was yellow, the bird was marked in the SRBOPA as a

Table 7. Nesting success and productivity of golden eagles in southwestern Idaho, 1992. Sample sizes are in parentheses.

Study Area	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	#Fledged Per Pair
SRBOPA	86% (29)	56% (16)	1.73 (19)	0.83
Comparison	95% (21)	63% (16)	1.70 (10)	1.02

nestling in 1976 or earlier. If the marker was yellow-blue, the bird could have been marked as a nestling in the SRBOPA in 1980 or earlier.

Ferruginous Hawk Occupancy and Reproduction

In 1992, 24 of 71 historical ferruginous hawk nesting areas in the SRBOPA (34%) were occupied (Table 8). These included 10 canyon, 10 bench, and 4 non-ISA nesting areas. Six of 12 OTA nesting areas (50%) were occupied, but only 4 of 17 non-OTA nesting areas (24%) were occupied. Ten

nesting areas not previously recorded were also occupied: 7 on the bench, 2 in the canyon, and 1 outside the ISA.

In the SRBOPA, 23 breeding attempts were confirmed at 22 nesting areas (Table 9). These included 3 canyon, 14 bench, and 5 non-ISA nesting areas. Fifteen (65%) of the breeding attempts were confirmed during incubation: 3 in the canyon, 10 on the bench, and 2 outside the ISA. Only 5 of the 15 SRBOPA nesting areas (33%) were successful: 4 bench and 1 canyon nest. Both non-ISA nests failed.

Table 8. Number of occupied historical ferruginous hawk nesting areas in the SRBOPA, 1992. Numbers in parentheses are sample sizes.

Area	# Historical Nesting Areas	% Historical Nesting Areas Occupied
Canyon	28	36% (10)
Bench	29	34% (10)
Non-ISA	14	29% (4)
SRBOPA	71	34% (24)

Table 9. Nesting success of ferruginous hawks in the SRBOPA, 1992. Numbers in parentheses are sample sizes.

Area	# Breeding Attempts ^a	% Breeding Attempts CDI ^b	% Attempts Successful CDI ^b
Canyon	3	100 (3)	33
Bench	15 ^c	67 (10)	40
Non-ISA	5	40 (2)	0
SRBOPA	23 ^c	65 (15)	33

^a with known outcomes

^b CDI= confirmed during incubation

^c includes a renest

Five benchland nesting attempts were within 1.5 km of the OTA, and 5 were not. Success rates were the same (40%) for both areas. Complete fledge counts were obtained at 5 of 12 SRBOPA nesting areas that fledged young. Fourteen young fledged from these 5 nests for an average 2.8 young fledged/successful attempt.

Nesting of Raptors on the Benchlands

General Survey Results.--In 1992, we located 94 occupied raptor nesting areas on benchlands in the ISA (Table 10), 30 more than in 1991. Twenty-two were inside the OTA, and 72 were outside the OTA. These included 17 ferruginous hawk, 9 northern harrier, 44 burrowing owl, and 24 short-eared owl pairs. Thirty-two of the 94 pairs were found during historical nest surveys, 16

were found during quadrat surveys, and 46 were found incidentally by Study 3 personnel and other study teams.

On a unit area basis, we found 0.039 nesting areas per km² inside the OTA and 0.050 per km² outside the OTA. However, 7 nesting areas considered outside the OTA for this analysis were on or very near the OTA boundary. These included 4 ferruginous hawk nests on the PP&L transmission line, which forms the OTA's northern boundary, and 3 nesting areas (1 each of the burrowing owl, northern harrier, and short-eared owl) that were within 100 m of the boundary. If these nesting areas are considered inside the OTA for the analysis, 0.052 nesting areas per km² were found inside the OTA and 0.046 nesting areas per km² were found outside the OTA.

Table 10. Number of occupied raptor nesting areas found on ISA benchlands in 1992 using different survey methods. Numbers in parentheses indicate percent of nesting areas found by each method.

Survey Type	Ferruginous Hawk	Northern Harrier	Burrowing Owl	Short-Eared Owl	Totals
Historical	7 (41)	2 (22)	19 (43)	4 (17)	32 (34) ^a
Quadrat	6 (35)	1 (11)	2 (5)	7 (29)	16 (17)
Incidental	4 (24)	6 (67)	23 (52)	13 (54)	46 (49)
Totals	17	9	44	24	94

^a Thirty-five historical nesting areas were occupied, but 3 were found during quadrat surveys or incidentally.

One hundred four historically occupied nesting areas in the ISA were surveyed sufficiently to determine occupancy. Thirty-five historical nesting areas were occupied. In 1992, we determined fate at 61 of 64 occupied nesting areas found in 1991. Twenty-six of these were reoccupied in 1991, for a reoccupancy rate of 42.6 percent. Occupancy rates at historical nesting areas inside and outside the OTA differed only slightly. Thirty-two percent of 31 historical nesting areas inside the OTA were occupied, compared to 36% of 73 nesting areas outside the OTA.

Seven of the 17 ferruginous hawk nesting areas on the benchlands had not been previously recorded. Four of these were found during quadrat surveys, and 3 were found incidentally. Of 14 nesting areas where breeding attempts were confirmed, 7 were on rock outcrops, the ground, or cliffs;

6 were on transmission towers or poles; and 1 was on an artificial platform. One pair initially nested on a rock outcrop then renested at a nearby ground nest. Both breeding attempts failed.

Seven of 9 occupied northern harrier nesting areas in the ISA benchlands had not been previously recorded. One of these was found during quadrat surveys, and 6 were found incidentally. Eight of 9 nests found were in thickets of dead Russian thistle (*Salsola iberica*).

Twenty of 24 occupied short-eared owl nesting areas and 25 of 44 burrowing owl nesting areas on the ISA benchlands had not been previously recorded. Of these, 7 short-eared owl nesting areas and 2 burrowing owl nesting areas were found during quadrat surveys. Of 10 short-eared owl nests found, 6 were in stands of big sagebrush (*Artemisia*

tridentata), 3 were in cheatgrass (*Bromus tectorum*), and 1 was in a thicket of dead Russian thistle. All burrowing owl nests except 1 were in ground-level burrows. One burrow in the Impact Area was excavated on top of an artificial berm supporting a moving target system.

Relative Abundance.—Forty-four quadrats were surveyed on ISA benchlands in 1992. Of these, 43 were surveyed twice, and 1 was surveyed once. Fourteen quadrats were surveyed inside the OTA, and 30 were surveyed outside the OTA. Twenty-six of 94 occupied nesting areas found on the benchlands were inside quadrats, but only 16 (17%) were first detected during quadrat surveys. Four of these were inside the OTA, and 12 were outside the OTA (Table 11).

As in 1991, short-eared owls were the most abundant of the 4 species, accounting for 7 of the 16 nesting areas found. We also found 6 ferruginous hawk, 2 burrowing owl, and 1 northern harrier nesting areas. We found 0.29 nesting areas per quadrat inside the OTA compared to 0.40 nesting areas outside the OTA; however, contingency table analysis of quadrats with and without nesting areas suggested that frequencies of occupied nests in the 2 areas did not differ ($G_1 = 0.283$, $P = 0.595$).

Ten nesting areas were missed during the first quadrat survey. Of these, 4 were found during later surveys of historical nesting areas, and 6 were found incidentally. One of the 10 nesting areas missed was found during the second quadrat survey. One ferruginous hawk, 1 northern harrier, 2 short-eared owl, and 5 burrowing owl nesting areas were missed during both quadrat surveys.

Nine nesting areas missed in quadrats were outside the OTA and 1 was inside the OTA. If these nesting areas are included in the analysis, raptor abundance outside the OTA appears to be higher than inside the OTA. The number of nesting areas found per quadrat inside the OTA increased to 0.36 and the number of nesting areas per quadrat outside the OTA increased to 0.70. However, contingency table analysis of quadrats with and without nesting areas again failed to detect significant differences in relative abundance inside and outside the OTA ($G_1 = 0.795$, $P = 0.519$).

The relatively low number of nesting areas detected during quadrat surveys (16 of 94) suggests that raptor nests on the bench are more likely to be encountered incidentally or at historically occupied nesting areas than within random plots. In comparison, 32 occupied nesting areas were found during surveys of historical nesting areas, and 46 were found incidentally. A total of 649 hrs of effort was spent during quadrat surveys, or 40.5 hrs per occupied nesting area. An average of 7.3 hrs per quadrat was spent inside the OTA and 7.4 hrs per quadrat was spent outside the OTA; yet, we found nests in only 20 of 44 quadrats. Surveys of 32 quadrats in 1990 and 768 transects and circular plots in 1991 also showed a low return per unit effort for random plot surveys (Lehman et al. 1990, Steenhof et al. 1991).

Nesting Success.—In 1992, breeding was confirmed at 71 of 94 occupied nesting areas found on ISA benchlands. These included 14 ferruginous hawk, 6 northern harrier, 39 burrowing owl, and 12 short-eared owl nesting areas. Two breeding attempts were confirmed at 1 ferruginous hawk nesting area. Of 72 breeding attempts, 39 were found during incubation. Twenty-six of

Table 11. Number of occupied raptor nesting areas found on ISA benchlands during quadrat surveys. Numbers in parentheses show the number of occupied nesting areas found per quadrat.

Species	Inside OTA (n = 14)	Outside OTA (n = 30)	Totals (n = 44)
Ferruginous Hawk	2	4	6
Northern Harrier	0	1	1
Burrowing Owl	1	1	2
Short-eared Owl	<u>1</u>	<u>6</u>	<u>7</u>
Total	4 (0.29)	12 (0.40)	16 (0.36)

these were successful, and 13 were unsuccessful. Of 15 ferruginous hawk breeding attempts, 10 were found during incubation (Table 12). Of these, 4 were successful and 6 failed. Of the successful nesting areas, 1 was in the OTA and 3 were outside the OTA, for nesting success rates of 33.3% and 42.9%, respectively. Of 6 northern harrier nesting areas where breeding was confirmed, 5 were found during incubation (Table 12). Two of these were successful; both successful nests were outside the OTA. These data suggest a lower success rate for these species inside the OTA, but sample sizes were too small for statistical comparison.

Our burrowing owl sample seemed heavily biased towards successful nests. Of 40 occupied burrowing owl nesting areas where fate was determined, 38 were successful and 2 were unsuccessful (Table 12). We found

22 pairs during incubation or before 3 May. Of these, 20 were successful and 2 were unsuccessful. One unsuccessful pair was found inside the OTA, and 1 was found outside the OTA. Nesting success rates inside and outside the OTA were 83.3% and 93.8%.

We were unable to compare nesting success of short-eared owls inside and outside the OTA because sample sizes were low and no successful nests were found during incubation (i.e., all pairs found during incubation failed and all successful pairs were found late in the nesting season) (Table 12). The behavior of nestling short-eared owls also complicated our attempts to confirm nesting success at some nesting areas. Nestling short-eared owls fledge at about 25 days of age but may leave the nest on foot as early as 14 days (Johnsgard 1990). At 3 nesting areas, we confirmed

Table 12. Nesting success of breeding raptors on ISA benchlands.

	Successful Nesting Areas		Unsuccessful Nesting Areas		Totals
	Found During Inc.	Found After Inc.	Found During Inc.	Found After Inc.	
Ferruginous Hawk	4	4	6	1 ^a	15
Northern Harrier	2	0	3	1	6
Burrowing Owl	20	18	2 ^b	0	40
Short-eared Owl	0	3	4	0	7
Totals	26	25	15	2	68

^a This attempt was a re-nest.

^b Breeding attempts were not confirmed at these unsuccessful nesting areas.

that young hatched but could not confirm that young fledged, possibly because they had left the nest before fledging. In addition, short-eared owl nests are inconspicuous and relatively difficult to locate. We found nests at only 12 of the 24 nesting areas identified.

Habitat Assessments.--Canonical discriminant analysis involving 9 continuous variables (Table 13) revealed a significant difference between nesting areas and random points ($F_{9,164} = 10.04$, $P < 0.001$). Factors that correlated with the canonical discriminant axis were badger holes, percent vegetation cover, soil depth, number of rock outcrops, and tank tracks. Nesting areas had fewer badger holes, less vegetation cover, deeper soils, more rock outcrops, and fewer tank tracks than random points (Table 13). Variables not important in discriminating the 2 groups were \bar{x} shrub height, species richness, vegetation diversity, and cow sign.

The discriminant analysis was probably influenced by the many burrowing owls in the analysis (44 of 92 nesting areas analyzed). A separate analysis of burrowing

owl nesting areas also showed a significant difference between occupied nesting areas and random points ($F_{9,116} = 6.89$, $P < 0.001$). As in the overall analysis, important discriminating factors were badger holes, vegetation cover, and soil depth. Burrowing owls nested in deeper soils where vegetation cover and badger densities were low.

Short-eared owls also nested in deeper soils with low badger hole densities. Both soil depth and badger burrow density were important factors in a significant ($F_{9,96} = 3.66$, $P = 0.001$) discriminant analysis involving random points and nesting areas occupied by short-eared owls.

Vegetation cover was not important in the analysis of short-eared owls, but short-eared owls nested in areas with significantly fewer tank tracks than at random points.

Rock outcrops, badger holes, and vegetation cover were the 3 most important factors in the discriminant analysis involving ferruginous hawks. Ferruginous hawk nesting areas had more rock outcrops, fewer badger holes, and less vegetation cover than

Table 13. Habitat characteristics at benchland sample points in 1992. Standard deviations are in parentheses.

	Nesting Area	Random Point
\bar{x} Shrub Height (cm) ^a	19.8 (20.4)	21.7 (21.7)
% Vegetation Cover	24.5 (13.8)	32.6 (13.5)
Species Richness	4.78 (1.71)	4.88 (1.63)
Vegetation Diversity	2.21 (0.81)	2.26 (0.83)
Soil Depth	2.24 (0.95)	1.84 (0.91)
Badger Holes ^b	7.1 (8.1)	40.4 (50.1)
Rock Outcrops ^b	0.79 (2.67)	0.15 (0.48)
Cow Sign	2.59 (1.52)	2.95 (1.56)
Tank Tracks	0.63 (1.41)	1.08 (1.68)

^a See text for variable definitions.

^b Actual counts: data were transformed using $\sqrt{x+1}$ in all analyses.

random points. None of the other variables differed significantly, but the discriminant analysis was significant ($F_{9,87} = 6.40$, $P < 0.001$).

Discriminant analysis failed to distinguish northern harrier nests from random points based on the few (9) harrier nests we sampled ($F_{9,81} = 1.99$, $P > 0.05$). However, harriers showed the same patterns as the other benchland raptors, nesting where badger burrow density was low and rock outcrops were numerous.

Significantly more nests occurred within 50 m of agriculture ($G_1 = 11.91$, $P = 0.004$), and more nests than random points had artificial structures within 50 m ($G_1 = 8.45$, $P = 0.006$). However, logistic regression models, using 5 continuous and 14 categorical variables, failed to predict occupancy by individual raptor species or by all species pooled.

Random points inside and outside the OTA had similar values for variables used in the discriminant analysis. Of all variables

analyzed only tank tracks differed: OTA random points had significantly more tank tracks ($t_{80} = 13.9$, $P < 0.001$) than random points outside the OTA.

Log-likelihood contingency table tests indicated that nests and random points had similar characteristics within 50, 100, and 500 m. Roads, perches, and hills were equally common near nests and random points, and frequencies of nests and random points in the 2 grazing regimes were similar. In 1991, habitat analyses indicated that benchland raptors nested where badger burrow and tank track densities were higher than at random points.

Nest Distribution in the OTA.--In 1992, we found raptors in all sectors of the OTA except 2 (B2 and B3). The frequency of raptor nesting pairs in sectors did not differ from the frequency of random points in sectors ($G_9 = 9.33$, $P = 0.41$), and the frequencies of OTA nests and random points inside and outside the impact area were similar ($G_1 = 0.03$, $P > 0.5$). Nests and random points occurred at similar distances from firing points ($\bar{x} = 4.6$ km for nests and 4.9 km for random points), but no nests were found within 1 km of the MPRC in 1992. Similar proportions of nests and random points occurred within and greater than 1 km of firing fans ($G_1 = 0.30$, $P = 0.77$).

■ DISCUSSION

Prairie Falcon Abundance and Reproduction

Abundance.--Current numbers of prairie falcons in the Snake River Canyon are similar to those of the mid and late 1970's. Numbers of pairs recorded in the 1970's

ranged from 206 in 1977 to 182 in 1978. In the 1990's, numbers ranged from 183 pairs in 1991 to 194 in 1992. However, 2 different survey methods (walking surveys and point surveys) were used during the 6 years (1976-1978, 1990-1992) with complete surveys of the SRBOPA. Walking surveys were used between 1976 and 1978, and point surveys were used in 1991 and 1992. In 1990, we used both methods and compared results (Lehman et al. 1990). Walking surveys may bias counts upwards, and point surveys may more accurately represent the actual number of pairs. We suspect that estimates of nesting abundance in the late 1970's and in 1990 may have been slightly higher than actual numbers, and that estimates in 1991 and 1992 are probably most accurate.

Reproduction.--In 1991 and 1992, we monitored reproductive success at 23% and 31% of the SRBOPA's occupied prairie falcon nesting areas. Falcon reproductive success appears to have held steady since the mid 1970's (Table 3).

Golden Eagle Abundance and Reproduction

Abundance.--The number of occupied golden eagle nesting areas in the SRBOPA has declined significantly since the 1970's. The number of occupied nesting areas held steady between 34 and 35 until 1977, and then dropped to 32 in 1978. Numbers fluctuated between 28 and 32 pairs from 1978 to 1988. Since 1989, golden eagle numbers have held steady at 29 to 30 pairs, down 5 to 6 from the early 1970's. Four of these nesting areas (A-56, Bruneau Bridge, Bruneau Flats, and Simpkin) have been vacant for at least 10 years, and 2 have been vacant for at least 14 years.

Two possible causes of the decline in golden eagle numbers might be the loss of foraging habitats by wildfires that have occurred primarily since 1980 (Kochert and Pellant 1986), and agricultural development that has occurred on private lands in and around the SRBOPA during the late 1960's and early 1970's. Since 1980, wildfires have converted much of the native shrub-steppe vegetation in these areas to open grassland composed primarily of cheatgrass (*Bromus tectorum*) and other exotic species (Yensen 1982). Smith and Nydegger (1985) found lower densities of black-tailed jackrabbits (*Lepus californicus*) in burned grasslands, suggesting that the loss of native vegetation has reduced jackrabbit numbers within golden eagle foraging habitat. Relationships between golden eagle numbers and habitat conversions due to wildfire and agriculture will be explored further when a vegetation map for the SRBOPA has been completed (see Knick et al., this volume) and when radiotelemetry work with golden eagles has been completed.

Reproduction.--Golden eagle reproductive success has varied widely since productivity surveys began in 1971 (Table 6), but this can be attributed primarily to cyclic jackrabbit abundance and secondarily to weather (U.S. Bur. Land Manage. unpubl. data). Golden eagle productivity appears to be closely linked to jackrabbit abundance prior to the breeding season, but winter severity may influence eagle productivity when jackrabbit abundance is low (U.S. Bur. Land Manage. unpubl. data). Eagle productivity increased between 1985 and 1990, and decreased in 1991 and 1992. In 1990, eagle productivity peaked at 1.15 young per pair.

Nesting of Raptors on the Benchlands

Relative Abundance.--In 1990, we found only 4 raptor nests during 2 surveys of 16 4-km² quadrats. At the time, we concluded that abundance of nesting raptors on the bench was low (Lehman et al. 1990). We found 64 nesting areas in 1991 using a combination of methods, including line transects, circular plots, surveys of historical nesting areas, and surveys of nesting areas found incidentally (Steenhof et al. 1991). In 1992, we found 94 nesting areas by surveying larger (9-km²) quadrats and again by surveying historical nesting areas and nesting areas found incidentally. Clearly, nesting raptors are more abundant on the benchlands than we originally thought.

Although we have found many previously unrecorded nesting areas during this study, the proportion of pairs found during random plot surveys (transects, circular plots, and quadrats) has been very low (4 in 1990, 15 in 1991, and 16 in 1992). In 1991 and 1992, pairs found during random plot surveys represented only 23% and 17% of all pairs found.

In 1992, we analyzed relative abundance in 2 ways: First, we analyzed only those pairs found during random sampling efforts. Second, we combined all nesting areas found inside quadrats, including those found at historical nesting areas and those found incidentally, to increase sample sizes. In both cases, numbers of nests inside the OTA were lower than numbers outside the OTA. Although overall efforts inside and outside the OTA were similar (7.3 hrs per quadrat inside the OTA vs. 7.4 hrs per quadrat outside the OTA), surveys may have been

biased because the level of effort expended in each quadrat was not standardized. In 1992, quadrats were surveyed until observers felt that all areas had been adequately covered, but efforts varied within different vegetation types. More time was spent in shrub environments than in grasslands.

We believe it will be necessary to continue some form of random sampling in the ISA for relative abundance assessments. Though sample sizes may continue to be low, random sampling offers the least biased approach to comparing relative abundance of raptors in areas exposed to military activity with unexposed areas. We believe also that quadrat surveys as designed for the 1992 bench survey are the most efficient approach. First, we found more nesting areas during surveys of large quadrats in 1992 than we found during surveys of small quadrats in 1990 and during circular plot and line transect surveys in 1991 (16 nesting areas vs. 4 and 15, respectively). Second, the sampling design allowed observers greater flexibility in their approach to finding nests. Lack of a fixed search pattern allowed observers to concentrate effort in areas with suitable habitat or in areas where birds were seen. Finally, the 1992 quadrat survey involved the least set-up time of all survey methods used because there were no centroids, transects, or boundaries to mark.

Nesting Success.--Our attempts to monitor nesting success of raptors on the benchlands were limited by small sample sizes and survey biases favoring successful nests. Problems encountered varied with species. We were able to confirm breeding during incubation and nesting success at most ferruginous hawk and northern harrier nesting areas, but the number of pairs found was too low for statistical analysis. This

may reflect naturally low numbers of both species on the benchlands. A helicopter survey of ferruginous hawk nesting areas during incubation, especially those on the PP&L power line, might increase sample sizes of pairs found during incubation. To increase sample sizes of northern harriers, survey efforts might be expanded to include more of the ISA; however, such an effort would require a substantial increase in labor and costs and probably would not substantially increase numbers of nests found.

We encountered 2 problems during burrowing owl surveys. First, because the species nests underground, it was impossible to confirm whether eggs had been laid when pairs were found. Second, we may have missed pairs that failed early in the breeding period. The overall nesting success rate of burrowing owls in 1992 (90.9%) was higher than rates reported in the literature. The highest we found was 88.8% reported by Thomsen (1971). In the future, we may improve our sample of nesting areas found early in the breeding period by concentrating our searches of historical nesting areas and quadrats during early morning or late evening hours when owls are most active (Eckert and Karalus 1987).

We were faced with 2 problems with short-eared owls: the difficulty locating nests and the problem of pre-fledging dispersal of young. In the future, we can probably find more nests by conducting intensive observations at suspected nesting areas, particularly at dawn or dusk. This would require more time but might result in a significant increase in number of nests found. The problem of monitoring nesting success in a species that leaves the nest on foot before fledging is more difficult.

However, an earlier fledge count before dispersal may be appropriate for this species. In Montana, researchers use percent of nesting areas that disperse young (prior to fledging) as a measure of nesting success (D. Holt, Institute for Owl Research, pers. commun.). Holt (pers. commun.) also suggested listening for food-begging calls at night to find dispersed young. Post-dispersal survival of short-eared owl nestlings needs to be determined. If mortality is low and there is a good correlation between brood size at 14 days (the earliest that nestlings are known to leave the nest on foot) and at fledging, percent of nests dispersing young might be an appropriate measure of nesting success for use in long-term monitoring of the species in the SRBOPA. Post-dispersal survival of short-eared owl nestlings could be determined by attaching leg-mounted radio transmitters to nestlings before they leave the nest and monitoring mortality rates.

Nest Distribution in the OTA.--In 1991 and 1992, we determined the relationship between nest distribution and military use by measuring distances from nests and random points to centers of military activity. However, the analysis was based on information about military sectors, artillery position areas, firing ranges, and the MPRC from the GIS, not on actual military use in 1992. We feel this analysis should be based on the temporal as well as the spatial component of military activity. In this way, we might address questions about the effect of military activity on raptor occupancy and nesting success during the previous and present year.

Burn Effects

As discussed earlier, this analysis has been deferred until accurate historic burn maps for

the OTA can be developed, and a vegetation map for the ISA has been completed. RRTAC is developing burn maps for the ISA as part of the RRTAC Global Climate Change Research Project (Kramber, this volume). A vegetation map is also under development for the ISA (Knick et al., this volume). Work on vegetation maps for other areas of the SRBOPA and Comparison Area have been deferred until after 1993. We recommend that mapping efforts be completed as soon as possible for all SRBOPA lands and the Comparison Area. Golden eagle productivity in the Comparison Area has been higher than in the SRBOPA for 8 of the last 9 years, and was higher again in 1992. Extending mapping efforts to include the Comparison Area will allow examination of the relationship between golden eagle reproductive success and habitat alterations in and near the SRBOPA.

" PLANS FOR NEXT YEAR

In 1993, we will continue prairie falcon, golden eagle, and ferruginous hawk abundance and productivity surveys throughout the SRBOPA. For the first time we will conduct a helicopter survey of selected ferruginous hawk nesting areas to confirm breeding during incubation. We will continue quadrat surveys on the benchlands to assess relative abundance of nesting raptors inside and outside the OTA; however, we will reduce the size of quadrats to 6-km² to obtain better coverage. As in 1992, we will attempt to assess occupancy and nesting success of benchland species at all historical nesting areas in the ISA. In 1993, we will concentrate our searches of historical nesting areas of benchland species and quadrats in the early morning or late evening hours to increase detection rates for

owls. We will also coordinate with the Idaho Army National Guard to obtain information on 1991, 1992, and 1993 use of the OTA for analysis of nest distribution and military use. Finally, we are considering a radio-telemetry study of short-eared owls to determine nestling survival in the period between dispersal from the nest and fledging.

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Influence of Military Training on the Behavior of Raptors in the Snake River Birds of Prey Area, 1992

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ANNUAL SUMMARY

We assessed the potential influences of military training on the ranging and foraging behavior of 31 radio-tagged prairie falcons (*Falco mexicanus*), 7 radio-tagged golden eagles (*Aquila chrysaetos*), and all raptors utilizing firing ranges in the Orchard Training Area (OTA) in 1992. Most findings were consistent with those reported in 1991. In particular, breeding prairie falcons: 1) showed no ill effects of wearing 13-g backpack radio transmitters, 2) exhibited bimodal activity patterns and were located more frequently around receiver sites outside of the OTA than inside the OTA, 3) were most often present on the bench above the canyon when wind and temperatures were moderate, 4) ranged over significantly larger areas if their nests were within the OTA shadow than if they were west of the shadow, 5) maintained similar rates of feeding their nestlings regardless of where their nest was located with respect to the OTA, 6) had ranges with distinct core areas including 1-5 activity centers, and 7) specialized on Townsend's ground squirrels (*Spermophilus townsendii*), but the diets of birds in the OTA shadow were significantly more variable than the diets of birds west of the shadow. Male falcons continued to provide most of the food for nestlings; females rarely left the canyon until their nestlings fledged. We quantified caching and retrieval of cached items in 1992 and found that birds nesting in the OTA shadow cached fewer items than birds west of the shadow. However, Townsend's ground squirrel populations were exceptionally high in 1992, and this may explain why falcons utilized the OTA less and ranged over significantly smaller areas (\bar{x} = 13,747 ha) in 1992 than in 1991. This was especially pronounced west of the OTA where males showed a reduced home range size and were associated with nearby agricultural fields.

Dispersal from the study area occurred earlier in 1992 than in 1991, probably because prey numbers declined rapidly in 1992 in response to extreme drought conditions.

All raptors using firing ranges were less abundant during firing periods than during periods of inactivity. The behavior of raptors on firing ranges was influenced by firing; northern harriers (*Circus cyaneus*) and falcons were affected most, tending to travel at greater heights more frequently on firing days and to travel low and hunt more frequently on non-firing days. Tank, mortar, and missile firing caused the greatest reduction in raptor use of the ranges. Activity associated with bivouac sites appeared to reduce raptor presence as well. We hypothesize that other military activity, peripheral to the firing ranges, may have significant effects on raptors foraging along the Idaho Power "Big Baja" power line on the southwestern edge of the OTA.

Individual golden eagle ranging habits varied, but home ranges were large (802 - 19,311 ha) relative to previous studies. Long excursions from the nest were especially common at territories near the Grand View feedlots and by females after nest failure. Home range size of females increased throughout the breeding season. Winter ranges of all eagles were smaller than breeding ranges. Copulation sites tended to be near the nest, and hunting sites tended to be far from the nest. Eagles were detected or observed hunting most frequently in moderately disturbed shadscale (*Atriplex confertifolia*) and riparian habitats.

■ OBJECTIVES:

1. Assess the impacts of backpack radio transmitters on the behavior and productivity of prairie falcons.
2. Determine the spatial use patterns of prairie falcons nesting in the OTA shadow and west of the shadow.
3. Assess the impacts of military training on the ranging habits, nesting behavior, and productivity of prairie falcons.
4. Assess the impacts of military training on the abundance and behavior of raptors utilizing firing ranges in the OTA.

5. Monitor habitat use of resident, adult golden eagles.

■ INTRODUCTION

Study 2 is responsible for assessing the potential influences of military training on the behavior of raptors nesting in and utilizing the Snake River Birds of Prey Area (SRBOPA). In 1992, we conducted the second year of intensive research designed to understand if, and how, this training influences the spatial use patterns, foraging behavior, and parental care exhibited by raptors. Our focus continues to be on the most abundant and farthest ranging raptor breeding in the SRBOPA, the prairie falcon. Our study approach to this species changed little from 1991; subtle changes in tracking and nest observation protocols are detailed in

the methods section. A more general view of short-term, immediate responses to military training is provided by our observations of all raptors utilizing firing ranges in the OTA. We expanded these observations slightly to include monitoring bivouac/maintenance sites in 1992. A second major focus of our research continues to be the golden eagle. This species serves as a model of how canyon dwelling raptors may respond to military training and, most importantly, illustrates how previous wildfires may influence raptor ranging and foraging behavior.

We continue to compare raptor abundance and behavior observed in the canyons and benchlands in and adjacent to the OTA (the "OTA shadow") with abundance and behavior west of the training area. This is not a perfectly controlled comparison of areas with and without military training. The western part of the study area that serves as the control area seems to differ in many respects from the military training area; soils may be deeper, rainfall may be greater, and vegetation may differ. Therefore, some differences in raptor abundance and behavior between the military and control areas may result from historical differences between the 2 areas. For example, raptors using the OTA may travel farther in search of prey because climatic conditions around their nesting areas provide less suitable habitat for prey. Such differences should, in general, result in an over-estimation of military effects. This adds an important conservative nature to our study; a failure to detect military effects is unlikely to be an artifact of study design.

The objective of this report is to present results from the 1992 season and, compare and contrast them with results from 1991.

We conducted many analyses on the combined 1991 - 1992 data set so that more robust conclusions could be drawn. However, despite 2 solid seasons of research, the variable nature of the Great Basin Desert environment precludes generalization of our results. Despite drought conditions in the study area, prey resources have been abundant in both years of the study. Therefore, we continue to view our results as a best case scenario of potential human impacts.

■ METHODS

Terminology

We use the same terms in 1992 to reference the space used by prairie falcons in the Snake River Canyon. A *nesting area* is a stretch of cliff where nests are found year after year, but where no more than 1 pair has ever bred at 1 time. A *territory* is defined as the cliff and canyon terrain actively defended by a pair in a given year. An *aerie*, *scrape*, or *nest* refers to the actual nest location.

A major change in terminology concerns the definition of the OTA shadow. After appraising the use of the OTA by all radio-tagged falcons in 1991, we expanded the OTA shadow to include nesting areas of falcons found inside the OTA boundaries at least 30% of the time. This expanded the OTA shadow to include the nesting areas within the 40 km of the Snake River Canyon immediately south of the OTA (BLM 10-km river units 6, 7, 8, 9). Nesting areas considered west of the OTA shadow include those northwest of the OTA shadow (units 4, 5). The area east of the OTA shadow remained unchanged and includes nesting

areas southeast of the OTA shadow (units 11, 12, 13).

We use 2 terms to define military activity. "Firing" describes the use of live ammunition. "Training" refers to firing as well as other training activities such as driving, bivouaging, laser firing, etc.

Trapping Prairie Falcons

Fifty-two historical nesting areas were investigated for prairie falcon trapping in 1992 (30 were from the Study 2 OTA shadow preselected list, 1 was from the Study 3 preselected list, 17 were from the Study 2 west of OTA shadow list, 6 were from the Study 2 east of OTA shadow list). We rejected 22 nesting areas because adults were not present or not exhibiting territorial behavior, Ferruginous Hawks (*Buteo regalis*) were nesting nearby, or trap placement sites were unavailable. We deleted 1 additional nesting area from the preselected list because the trap was placed in an adjacent nesting area and the captured resident was fitted with a transmitter before we detected the error. We set traps during courtship, egg laying, and incubation in 34 areas (33 historical areas and 1 previously unknown area [Tadpole Lake]), and captured 37 adult prairie falcons from 35 territories during March, April, and May 1992.

Nesting areas selected for trapping were a random sample of all areas previously stratified into 3 categories: those within the OTA shadow, those west of the OTA shadow, and those east of the OTA shadow. Eighteen of our captures occurred west of the OTA, 17 occurred in the OTA shadow, 1 occurred east of the OTA shadow, and 1 occurred within the OTA. We placed a radio transmitter on each captured falcon

unless we believed that the trap was not set within the preselected area. We placed radio transmitters on 34 falcons (15 birds in the OTA shadow, 17 birds west of the OTA shadow [2 of which shed transmitters during the trapping period, and different individuals were captured when the sites were retrapped], 1 east of the OTA shadow, and 1 that was nesting within the OTA (Appendix A).

Two teams trapped from 17 March through 20 April 1992. They observed each nesting area until a falcon exhibited signs of occupying the area (perching, courting, copulating, or defending the area), and then placed traps within (or as close as possible to) the territory. A single team trapped on 27 April to reapply a lost transmitter and on 12 May to trap a member of the pair found nesting within the OTA. We used the owl/dho-gaza method described in Marzluff et al. (1991), except that we used drag lines connected to each lower corner of the 2 nets, instead of a single connection in the center of each net.

When an individual was captured, it was restrained immediately and hooded (Bloom 1987). Each unbanded falcon was marked with a USFWS aluminum band on the left leg and a black alpha-numeric band on the right leg. We collected the following information on each bird (see Marzluff et al. [1991] for methods): weight adjusted for crop content, wing chord, wing span, seventh primary length, foot pad, molt, and a general description of the bird's condition (including observations of injuries, or presence of brood patches). Crop content (percentage full in 25% categories) was also recorded. Sex was estimated based on wing chord (U.S. Fish and Wildlife Serv. 1991).

We applied 12-13 g radio transmitter backpack packages (see Marzluff et al. 1991). One modification was made this year; knots were placed between the ends or on the underside of the Teflon® straps and then glued to reduce the ability of falcons to pick at them. Birds were released as soon as the attachment was completed.

We monitored each falcon for at least 1 hr after release to determine if the transmitter package and/or handling adversely affected the bird's flight or behavior. Each bird was monitored again for 2 hr (in most cases on the next day) to ensure that the transmitter was still on and that the bird's behavior appeared normal.

At least 10 birds radio tagged in 1991 did not shed their transmitters. We captured 1 (the CSJ male) during our regular trapping schedule and removed the radio, and recovered another transmitter (the Beercase male) when the individual was found injured. We observed little sign of feather wear or skin irritation in either case.

Band combinations and physical characteristics of all falcons captured in 1992 are listed in Appendix A.

■ PRODUCTIVITY

Field protocol.--We monitored the breeding status of 29 pairs of prairie falcons that included a radio-tagged individual, and 1 female falcon (captured in the Red Trail nesting area) that did not occupy a breeding territory. We observed aeries and measured young as described in Marzluff et al. (1991). At 3 aeries (Falcon Flats Cave East, Peregrine Chimney, and Henderson Draw) we were unable to see all of the nestlings because the cavities were so extensive.

Unlike 1991, these sites were not viewed from the ground to obtain an accurate nestling count. In addition, we could not determine nestling counts at 4 sites (Hell Hole Gate, Mother Giant Upstream, Swan I Draw Mouth DS, and Beercase Downstream) due to premature fledging and the subsequent inability to account for all young. We monitored unsuccessful aeries as described in Marzluff et al. (1991).

Analysis.--We tested the null hypothesis that radio transmitters had no effect on nesting falcons using the same methods as in Marzluff et al. (1991).

Radio Telemetry

Field protocol.--After conducting beacon tests during winter 1992, we adjusted the locations of our tracking zones to maximize coverage of the study area. The study area was divided into 8 zones ranging in size from approximately 70 to 120 km². These zones were small enough to allow detection of most birds using the area. Each zone included 6 permanent receiver sites. Most were located on prominent buttes, ridges, and outcroppings, but some were located on flat terrain (Fig. 1). Receiver positions were surveyed with a global positioning system accurate to within 5 m. Receiver positions were distributed within the zone to allow simultaneous bearings taken on birds in the zone to cross at approximately right angles, thereby minimizing triangulation error (White and Garrott 1990). All monitoring sessions for a given zone used the same 6 receiver positions.

Radio-tracking team members were trained as they arrived throughout the season. Each person became familiar with the equipment, receiver positions, and protocol by

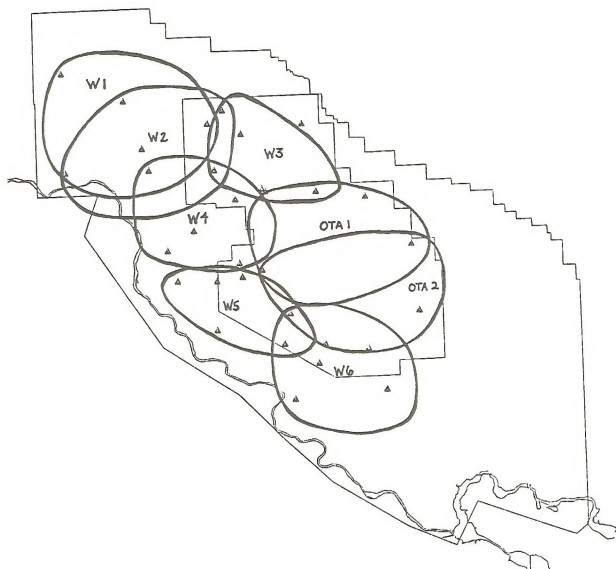


Fig. 1. Zones used for radio tracking (circles) in 1992 and locations of receiver sites (triangles). The OTA boundary (thin, solid line), the Integrated Study Area boundary (thick, solid line) and the north rim of the Snake River Canyon (dotted line) are shown for orientation; north is oriented towards the binding.

estimating the location of stationary and mobile beacons and instrumented falcons before they began intensive radio-tracking.

In 1992, we changed from a 4-person tracking team (Marzluff et al. 1991) to a 6-person team. This increased our ability to accurately triangulate on falcons. However, it decreased the time spent tracking each day because we tracked only 1 zone per day rather than 2 per day as in 1991. The greater accuracy per tracking session in 1992 more than compensated for the reduced time spent tracking; we obtained more fixes with error ellipses <1,000 ha in 1992 than in 1991. Each zone was sampled once in the morning (30 min before sunrise to 1330 hrs) and once in the afternoon (1330 hrs until approximately sunset) during each of 2 time periods (15 April - 15 May and 2 June - 1 July). During the rest of the field season, each zone was sampled from 0800 to 1400 hrs. By sampling during this time period, many falcons were contacted (see Fig. 6 in Marzluff et al. 1991) and tracker fatigue was minimized.

We randomly selected the order for sampling zones, with 1 exception: once per week 1 team tracked the zone most likely to produce fixes on currently under-sampled birds. This strategy allowed us to adequately sample a larger percentage of birds in 1992 than in 1991, but produced an unbalanced tracking effort per zone. Combining all samples throughout the season resulted in a sampling effort per zone as follows: zone W1 = 7 samples, W2 = 14 samples, W3 = 6 samples, W4 = 15 samples, W5 = 9 samples, W6 = 16 samples, OTA1 = 7 samples, and OTA2 = 7 samples. This unbalanced sampling per zone represented a relatively equal intensive sampling of the 4 major regions of the study area (14-16 samples in each of the

following: western area [W2], eastern area [W6], central area [W4], and firing range area [OTA1 and OTA2]), plus a less intensive sampling of zones in between these areas (6-9 samples at W1, W3, and W5).

We tracked under all weather conditions unless lightning, high winds, and/or heavy rain threatened personnel and/or receiving equipment.

Each member of a tracking team was positioned at 1 of the receiver positions within the zone. Trackers used 4-element Yagi antennas and programmable scanning ATS receivers to sequentially sample for radio frequencies of instrumented falcons. Hand-held antennas were used at positions atop prominent buttes as in 1991, but we increased the reception range at low sites by placing antennas on 7-m tall towers in 1992. Trackers alerted team members to the presence of a falcon in the sampling area, and a coordinator called for a simultaneous bearing to be taken on each bird as described in Marzluff et al. (1991). As in 1991, we allowed at least 30 min between successive fixes of < 1,000 ha on the same bird. This was sufficient time for a falcon to easily traverse the study area and distributed our fixes throughout the study period, thereby assuring that our sample of fixes was representative of the falcons' use of the study area (White and Garrott 1990).

We continued to monitor falcon use of the study area until all birds dispersed. Most birds were no longer in the study area after 5 August so we sent a single observer to 3 prominent receiver sites (Initial Point, Bigfoot Butte, and Dorsey Butte) from 7 August to 15 September to quantify the gradual dispersal of falcons from the area. These trackers scanned for birds from 0800-

1400 hrs (2 hrs per site, sites visited in random order) and then drove in search of falcons to determine if radios had been shed and/or to obtain visual observations of the few remaining birds.

We supplemented our ground-based tracking efforts with 7 aerial searches of the study area from 27 April to 30 July. We flew a Cessna 180 outfitted with 1 rotatable, belly-mounted, H-antenna for 3-4 hrs each trip. We obtained at least 1 fix per bird during these flights and searched for dispersing falcons. Aerial fixes were not included in analyses of spatial use patterns.

Analyses.--As in 1991, we used Lenth's (1981) maximum likelihood estimator to determine an error ellipse around each triangulation estimate. In 1992, we did not specify an average bearing error, but instead let the estimator determine error based upon the geometry of the bearings included in each fix. We took this approach because of variability in bearing error associated with sites and distances from the site to the transmitter.

Location estimates were entered into Kenward's (1990) RANGES IV program to calculate home range size, characterize its shape, determine overlap among home ranges, and compute average and maximum travel distances from aeries and other centers of activity. Home ranges were estimated with harmonic mean methods (Dixon and Chapman 1980), peeled polygons centered at the aerie, and cluster analyses (Kenward 1987). We used a 40 x 40 grid and positioned fixes in the center of grid squares before calculating the harmonic mean isoclines to reduce plotting error (Spencer and Barrett 1984).

We recorded weather at 1 receiver site during each tracking session using a portable weather station. Temperature 0.5 m above ground in the shade, and wind speed and direction 2 m above the ground were recorded. Mean and maximum values for each weather factor were recorded every 15 min and later averaged per hr.

We expanded our measurement of the general activity of prairie falcons in the study area by recording the number of birds contacted and the number of contacts resulting in fixes with error ellipses < 1,000 ha each hr from 13 prominent receiver sites (10 in the OTA and 3 west of the OTA). Contact rates through the season were correlated with wind speed and temperature. We compared rates among groups (OTA versus west of OTA) using a 1-way repeated measures ANOVA. Analyses were done separately for 2 response variables (the average number of birds contacted per hr and average number of good fixes [error < 1,000 ha] per hr). The analysis had 1 between-subjects factor (OTA, west of OTA, south of OTA) and 2 repeated measures factors (3 daily time intervals [0500-1000, 1100-1400, and 1500-2100] crossed within 3 seasons [1 April-15 May, 16 May-15 June, and 16 June-1 August]). Multivariate tests (F approximations of Wilks' Lambda) were used to assess significance of the repeated measures factors.

We calculated the straight-line travel distance from the nest to each fix in 1992. The distances were then compared in 2 analyses of variance to determine if they differed with respect to the bird's sex or stage in the breeding cycle, the activity on the training ranges (firing or not firing), and the location of the aerie (in the OTA shadow or west of the shadow). The first ANOVA

had 3 factors (aerie location, breeding stage, and sex). The second ANOVA had 3 factors (aerie location, firing activity, and sex) and 1 covariate (breeding stage).

We quantified falcon association with agricultural fields by determining the percentage of a falcon's home range that overlapped fields. Using RANGES IV (Kenward 1990), we calculated the 95% harmonic mean home range for each falcon and overlaid it upon a digitized map of agricultural fields planted in 1992. We surveyed fields from the ground, determined their location with a global positioning system, and then identified and digitized field boundaries on a 1992, 1:24,000 scale thematic mapper image of the study area.

Behavior of Prairie Falcons in Territories

Field protocol.--We monitored 16 of the 32 instrumented falcons in their territories to determine prey delivery rates from 28 April - 18 June. Eight of the territories were within the OTA shadow, and 8 were west of the OTA. Each territory was watched for an average of 49.6 hrs (range = 14.5 - 99.0) over an average of 3.3 days (range = 1 - 7). Observations were made from blinds placed to optimize our view of the scrape and minimize disturbance (\bar{x} distance from blind to aeries = 132 m, range = 84 - 182 m; following Holthuijzen 1990). All scrapes were viewed from below nest level, although at 4 sites we were able to see directly into the nest. Blinds were set up for the entire field season at all territories except for 4 sites west of the OTA (Halverson Spring, Cattleguard Upstream, Ogen GE77, and Falcon Flats Cave East) where we used a truck (sitting inside or next to it) or a portable blind for observations. We

observed only pairs that did not fail and where the radio-tagged bird did not lose its transmitter.

We observed territories from 20 min before sunrise to 15 min after sunset as described in Marzluff et al. (1991). In total, we completed 53 full days of observation.

As in 1991, we maximized the number of territories observed rather than the number of days each territory was observed. All but 1 nest was observed at least once during early brood-rearing (nestlings < 21 days old) and once during late brood rearing (nestlings 21-40 days old). On average, each territory was observed 1.5 days during early brood rearing (range = 2-4 days) and 1.6 days during late brood rearing (range = 1-3 days). An additional 5 days were spent observing 3 OTA shadow territories and 2 western territories during incubation. Our observation schedule was not randomized because of logistical constraints (territories close to each other were observed during the same week) and military training schedules (territories in the OTA shadow were observed on firing and non-firing days).

Eight observers divided into 2 groups conducted all behavioral observations. One group observed the OTA shadow territories and the other group observed the territories west of the OTA. Differences between observers were minimized by training which included recording data from a video tape of wild breeding peregrine falcons (*Falco peregrinus*) and observing prairie falcons in the field for 1 day prior to making behavioral observations. Each observer made morning and afternoon observations, watching nests with 10 x 50 binoculars and 15-45x spotting scopes. Temperature and wind speed were recorded using portable

weather stations as described earlier in the radio-tracking methods.

We obtained complete counts of fresh prey items delivered into the territory, prey items delivered to the scrape (both fresh and cache retrievals), and prey items cached (both fresh and remains left over after young were fed). If a prey item's source (fresh or cache retrieval) was undetermined, we classified it as unknown. Only fresh items were included in counts of deliveries to the territory to reduce multiple counting of cached items. We identified the sex of the bird involved in the prey transaction by the presence or absence of bands or a transmitter. Deliveries into the territory, whether taken to the nest or cached, and cache retrievals taken to the nest were credited to the sex that was responsible for securing the prey item by hunting or retrieving it. This reduced the female bias in delivery rate to the nest because food items transferred from the male to the female are credited to the male, despite the fact that the female actually carried it to the nest.

We classified the prey delivered by species (Townsend's ground squirrel and kangaroo rat [*Dipodomys* spp.]) or class (mammal, bird, reptile, or insect) when possible; other prey items were recorded as unidentified.

We used laptop computers in the field to record observations of the parents' time budgets. The following behaviors were reliably recorded at each territory: (1) the total time at least 1 parent attended the scrape, (2) the time each parent spent in the nesting territory, and (3) the total time the instrumented bird was in radio contact. The time parents spent in the nest territory was assessed by visually scanning the territory

from the blind. The time parents were visible in their territory was recorded as a measure of territory attendance. To determine if we actually underestimated attendance because of the difficulty of observing birds on the cliff, we monitored instrumented falcons using a receiver with an omni-directional antenna mounted on top of the blind and recorded the radio contact time of the instrumented adults. We also recorded the time spent perching, brooding, incubating, feeding young, and feeding self and noted the occurrence of copulation, intra- and inter-specific interactions, and human activity.

Analyses.--We tested the null hypothesis that military training does not influence parental behavior by comparing behavior at sites in the OTA shadow to behavior at sites west of the OTA. As in 1991, we considered the nesting area to be the sampling unit and used the number of deliveries to the scrape and parental attendance at the nest and in the territory as dependent variables. In addition, we paid particular attention to caching behavior in 1992 and therefore also used the number of caches/hr, number of retrievals/hr, and deliveries of fresh prey to the territory/hr as dependent variables. We had complete observations at 16 nests and used a repeated measures ANOVA with a 2-level between subjects factor (nesting areas in the OTA shadow versus west of the OTA) and 2 repeated measures (age of young and sex of parent) as described in Marzluff et al. (1991). Univariate tests were conducted on the repeated measures factors because each measure had only 2 levels. Multiple days of observation within each age interval were averaged to increase the normality of the response variables. Percentages were transformed (arcsine of their square root) prior to analysis.

The effects of brood size and hatch date (recorded as Julian date) were investigated by correlating these measures with our measures of parental attendance and prey delivery rate. We also used these 2 variables as covariates in the repeated measures ANOVAs described above. Homogeneity of slopes was tested and confirmed prior to analysis of covariance.

The influence of nestling age was further investigated by correlating the daily average value for each behavior with the estimated average age of the chicks. The probability associated with these correlations may be inflated because repeated daily observations at the same nest are not independent.

We sampled behavior of falcons nesting within the OTA shadow on 13 pairs of days (within 1 - 5 days of each other); 1 day in each pair when no firing occurred on the OTA ranges and the other day when firing occurred on at least 1 range. Average behavior on firing versus non-firing days was compared with a repeated measures analysis of variance. The model had 1 repeated measures factor (firing versus non-firing).

Behavior and Abundance of Raptors on Training Ranges

Field protocol.--We monitored abundance and behavior of raptors on 13 training ranges and 2 bivouac/maintenance areas for a total of 51 days (87 observer days) during March, April, May, June, and July 1992. The ranges were located inside the Range Road and extended toward an artillery impact area (see Marzluff et al. 1991; Fig. 2). The bivouac/maintenance areas were located outside of Range Road. Our study areas on ranges were described in Marzluff et al.

(1991) and included 5 tank training ranges (ranges 1, 5, 10, 11), 2 small arms firing ranges (ranges 14, 15), 2 mortar ranges (ranges 26, 30), and 4 ranges used for a variety of driving and firing activities (ranges 22, 2, 3, 4). Scanning procedures at firing ranges, behaviors recorded, and military activity categories were described in Marzluff et al. (1991). In 1992, we added 3 activities for "Demolition" (preparation, blasting, and idle) to the military catalog and added 1 behavior (KT = kiting) and deleted another (QU = quartering) from the behavior catalog.

Bivouac/maintenance study areas differed from those at ranges. The "in-fan" area was the arc from the observer that delimited the area occupied by the military. The left and right "out-of-fan" areas continued the scanning arc such that they each equalled the angle of the in-fan area, exceeding the 180-degree scan at training ranges.

The standard observation period at both training ranges and bivouac/maintenance sites began at approximately 0600 hrs and continued until 1400 hrs (MST). We sampled 1 range 5 times from 0600 hrs until dusk (approximately 2040 hrs).

During each observation period, a portable computerized weather station recorded temperature, wind speed and direction, and high wind speed every half hour, as described earlier in the radio-tracking methods.

Each range was sampled on days that training occurred and on days when no training occurred. We conducted pairs of observations on training and non-training days on each of 13 ranges. Each daily survey of raptor and military activity was

conducted by a single observer. Five individuals acted as observers, 3 of whom surveyed ranges during both the 1991 and 1992 study seasons. Each individual surveyed most ranges at least once on a training day and once on a non-training day.

We expanded our analysis of hunting behavior on the ranges by totaling the number of attacks observed on each of 15 ranges in 1991 and 1992 and dividing by the number of hours each range was observed to create an average hourly attack rate per range (1 day is the experimental unit). These rates were analyzed with a 2-factor repeated measures ANOVA. The military activity on the range (training versus non-training) and location of the attack (inside versus outside of the firing fan) were the repeated measures for each range.

Golden Eagles

Trapping and observations.—We selected golden eagle territories for trapping as described in Marzluff et al. (1991). We began intensive trapping efforts on 13 October 1991 and continued until 16 January 1992. We first scouted territories to determine locations of regularly used perches and areas suitable for placing traps. We scouted for variable periods of time before trapping; some territories were familiar to us from early 1991 trapping efforts, with regular perching sites well documented, whereas other territories were visited for the first time.

We placed trap sets in view of habitual perch locations or along regularly used flight paths. We avoided trapping on elevated areas or near the canyon rim where trapped eagles could potentially gain lift and fly with traps. Initially, each set consisted of 4 #3

leghold traps placed around a jackrabbit (*Lepus californicus*) carcass. Our observations indicated that the eagles often approached carcasses near the head or abdomen, so we later added 2 more traps to our sets and concentrated the traps in the following areas: 2 traps near the head, 2 near the abdomen, and 2 along the back. We used old traps with relatively weak springs and padded the jaws with a double layer of heavy suede leather wrapped with electrical tape. We connected pairs of traps by their chains so there would be sufficient weight to keep eagles from flying away with traps (we added an extra length of heavy chain to pairs of traps with very short chains). To verify that eagles would not be harmed by the trap jaws, we tested each trap by tripping them with a bare hand.

At the trapping sites, we placed fiberglass insulation under the pans to keep dirt from being packed underneath them and to help prevent non-target species from being trapped. We placed traps in a shallow trench dug around the jackrabbit carcass, and filled in around the traps with dry soil. A small amount of soil was lightly sprinkled over the pans to complete the camouflage. We wired the carcass to 2 stakes driven into the ground in the area of the neck and hind-quarters, and completed the set by opening the carcass and spreading fur around the area to simulate a kill site. Use of 2-way radios buried near sets helped us to control the activity of non-target species. Corvids were frightened away from sets when static was broadcast but they would usually flush only a short distance, thereby remaining as lures to eagles. Static or voices broadcast over the radio also prevented coyotes (*Canis latrans*) from approaching the sets. We observed sets from trucks parked a minimum of 1.6 km away.

We determined the sex of all captured eagles using the criteria in Edwards and Kochert (1986). Observations of parental behavior confirmed these assignments for all breeding birds. Eagles with white on the proximal portions of their rectrices and lacking obviously old rectrices were considered to be juveniles (young of the year). This was confirmed by observing all juveniles in close association with adults, presumably their parents. Eagles with white on the proximal portions of their rectrices and some worn and faded feathers (feathers at least 1 year old) were classified as subadults. Eagles with completely dark tails were considered to be adults. Captured eagles were handled as described in Marzluff et al. (1991).

Instrumented eagles were followed on randomly selected days, 3-4 times per month when they were within the study area (territorial pairs) and sporadically when they left the study area (wandering fledglings or subadults). Observation periods lasted approximately 8 hrs and began before dawn and lasted until early afternoon or began in the early afternoon and continued until sunset. We homed in on the transmitters until visual contact was made and then continuously recorded the behavior and location of instrumented birds, particularly noting where foraging occurred and characterizing habitat for those areas. Locations were plotted in the field on 1:24,000-scale topographical maps. Aerial photographs were used to assist in determining a location. The amount of time each eagle was observed and the number of locations determined for each bird is reported in Table 1. We also recorded behavior of any eagle(s) associated with the instrumented bird.

Nestlings of 2 radio-tagged parents (at Cabin and Beercase) were banded and marked with uniquely-numbered patagial tags (Appendix B). This will aid in observations within territories this winter.

Analyses.--We recorded locations of each member of each eagle pair continuously throughout a monitoring session. Location estimates were obtained for all perched birds, all extreme points used by birds each day, and points where birds soared in a relatively stationary area. We also estimated the locations of all copulations, undulating flights, and hunting attempts. Travel routes between perches or soaring areas were recorded, but point locations along these routes were not estimated.

Analyses of spatial use patterns do not include all locations we estimated. We used observations only on the radio-tagged member of the pair, because this individual was the focus of our observations and all locations on the untagged pair member fell within the tagged member's home range. We also used only the subset of unique locations recorded each day for the radio-tagged eagle in computing home range. This reduces dependency between locations within a sampling day, and does not reduce the estimation of the maximum area used by an eagle. However, because many locations within a range are repeatedly visited each day and these tend to be near the center of the range, exclusion of repeat locations usually increases core area estimations.

In this report we present home range estimations defined by maximum convex

Table 1. Radio-tracking intensity for golden eagles studied, 1991-92.

Nesting Area ^a	Month/Year Studied	Unique Fixes	Total Fixes	Days Tracked	Total Time (hr)	
					Tracking Bird	Bird in View
BrCs	Jan, Feb 92	36	46	8	40.3	27.7
	Mar, Apr 92	32	42	5	24.7	17.6
	May, Jun, Jul 92	78	128	8	55.8	30.2
BlkBt	Nov, Dec 91	61	88	7	29.1	12.6
	Jan, Feb 92	54	76	6	29.0	19.7
	Mar, Apr 92	50	69	7	40.9	21.4
	May, Jun, Jul 92	60	117	9	59.5	47.2
Cabin	Dec 91	8	8	2	4.0	4.0
	Jan, Feb 92	34	45	8	27.0	11.9
	Mar, Apr 92	14	21	4	25.6	6.3
	May, Jun, Jul 92	61	82	7	52.0	32.5
GVSC	Jan, Feb 92	41	64	9	33.0	17.5
	Mar, Apr 92	30	63	7	42.7	39.3
	May, Jun, Jul 92	22	37	5	26.9	5.6
Wildh	Oct, Nov, Dec 91	37	47	8	37.8	10.4
	Jan, Feb 92	37	70	8	33.8	15.1
	Mar, Apr 92	6	16	2	9.9	8.0
	May, Jun, Jul 92	18	48	6	41.9	18.4
Beech	Dec 91	47	53	3	19.6	14.0
	Jan, Feb 92	71	92	5	28.1	15.5
	Mar, Apr 92	30	44	4	23.3	11.2
	May, Jun, Jul 92	55	129	6	42.5	26.2
PL119	Oct, Nov, Dec 91	52	64	10	37.1	17.4
	Jan, Feb 92	45	68	7	44.7	27.4
	Mar, Apr 92	23	52	4	27.4	21.5
	May, Jun, Jul 92	19	38	5	30.2	13.6

^a Nesting areas are abbreviated as follows: BrCs = Beercase, BlkBt = Black Butte, Cabin = Cabin, GVSC = Grandview Sand Cliff, Wildh = Wildhorse, Beech = Beecham, PL119 = PP&L 119.

polygons and harmonic mean analysis. We are currently investigating methods for estimating home range size that adjust for time spent at each location (Samuel and Garton 1987).

We calculated the distance traveled from the aerie to each point used in home range analyses. We also calculated travel distances to each prey capture attempt, each prey capture, and every instance of undulating flight.

Home range size and travel distance were calculated within 4 time periods that corresponded with major changes in the nesting phenology of eagles. The "winter" time period began when we captured each eagle (October - December 1991) and included observations before breeding activities began. Two eagles (female at Grandview Sand Cliff, and male at Beercase) were not captured until January 1992, and therefore winter observations were unavailable. The "courtship" period was defined as January and February and included observations before pairs began to incubate eggs. The "early breeding" period was defined as March and April and included observations of incubating birds and birds tending young nestlings. The "late breeding" period was defined as May, June, and July. This period included observations on 3 pairs tending nestlings and fledglings (female at Cabin, male at PP&L 119, and male at Beercase), and observations on 2 pairs whose nestlings died from suspected extreme exposure or parasite infestation (females at Grandview Sand Cliff and Wildhorse) and 2 pairs whose nestlings died from unknown causes (males at Beecham and Black Butte).

We used all observations on both members of the pair to determine locations of hunting attempts and prey captures. We defined a hunting foray as any flight that included an attempt to capture prey (a steep dive or chase of potential prey). The number of dives or stoops within a foray was also recorded. We determined which member of the pair initiated the hunt and which made the kill whenever possible. The habitat within approximately 50 m of all capture attempts was recorded by walking to the site after feeding ended or by observing from a distance with a spotting scope if key habitat components were identifiable. Habitat was classified according to the BLM habitat classes (Knick, this volume). We also recorded the relative abundance of all shrubs, grasses, and exotic annuals at each capture site.

Eagle data are presented primarily as descriptive statistics because the sample size is still too small to partition into groups defined by sex or burn history of the territory.

■ RESULTS

Activity of Prairie Falcons Inferred From Radio Telemetry

Influence of telemetry packages.--There continued to be no significant impact of radio-tagging on the behavior and productivity of prairie falcons in 1992 (Table 2). We observed little immediate non-typical behavior when we released newly instrumented birds. Falcons behaved normally during the first hour that they wore transmitters; they typically preened around

Table 2. Tests of effects of backpack radio transmitters on different measures of prairie falcon nesting success and behavior.

	1991									1992									1991 & 1992								
	Instrumented			Control			stat ^a	df	P	Instrumented			Control			stat ^a	df	P	Instrumented			Control			stat ^a	df	P
	n	mean	sd	n	mean	sd				n	mean	sd	n	mean	sd				n	mean	sd	n	mean	sd			
Nesting success (%)	26	73.0	--	42	81.0	--	0.57	1	0.45	29	86.0	--	56	75	--	1.52	1	0.22	55	80.0	--	98	77.6	--	0.13	1	0.72
Number of young fledged																											
All pairs ^b	24	2.88	2.09	34	3.06	2.06	0.12	54	0.74	23	3.7	1.89	44	2.84	2.13	2.61	65	0.11	47	3.28	2.02	78	2.93	2.09	0.8	121	0.37
Successful pairs	17	4.06	1.09	24	4.08	1.18	0.004	54	0.95	19	4.47	0.84	30	4.17	1.02	1.2	47	0.28	36	4.28	0.97	54	4.13	1.30	0.44	88	0.51
Average nestling weight (g)																											
Males	25	600.8	55.7	44	557.6	25.1	11.5	65	0.00	41	546.7	43.9	51	559.7	39.0	0.02	88	0.90	65	560.7	42.9	95	558.7	29.5	3.1	156	0.08
Females	30	839.2	73.9	49	829.5	50.5	0.004	75	0.95	43	795.0	71.7	73	813.3	61.7	0.09	112	0.77	73	810.3	79.1	122	818.8	57.9	0.01	191	0.94
Prey Delivery (items/hr)																											
Nestlings < 21 days old																											
Males	9	0.27	0.10	5	0.23	0.04	0.59	12	0.46	8	0.24	0.11	7	0.28	0.17	0.22	13	0.65	17	0.25	0.10	12	0.26	0.13	0.02	27	0.90
Females	5	0.13	0.09	9	0.25	0.15	2.56	12	0.13	7	0.22	0.10	8	0.13	0.07	4.2	13	0.06	12	0.18	0.10	17	0.20	0.13	0.06	27	0.81
Nestlings ≥ 21 days old																											
Males	9	0.20	0.06	5	0.16	0.15	0.71	12	0.42	8	0.32	0.16	7	0.23	0.09	1.3	13	0.28	17	0.27	0.14	12	0.20	0.12	1.9	27	0.18
Females	5	0.15	0.07	9	0.21	0.12	0.96	12	0.35	7	0.24	0.17	8	0.18	0.15	0.62	13	0.45	12	0.20	0.14	17	0.19	0.13	0.08	27	0.79
Attendance at nest ^c																											
Nestlings < 21 days old																											
Males	9	8.7	8.7	5	16.1	11.8	0.02	12	0.88	8	17.2	9.0	7	15.7	6.8	0.13	13	0.73	17	17.0	8.6	12	15.9	8.7	0.13	27	0.72
Females	5	11.7	11.7	9	39.6	11.7	1.44	12	0.25	7	38.4	14.5	8	41.1	16.1	0.09	13	0.77	12	35.7	13.3	17	40.3	14.5	0.77	27	0.39
Nestlings ≥ 21 days old																											
Males	9	10.3	9.4	3	3.9	2.9	--	--	--	8	9.1	4.6	7	5.4	3.3	3.0	13	0.11	17	9.7	7.3	10	5.0	3.1	3.8	25	0.06
Females	3	8.9	3.7	9	16.8	11.2	--	--	--	7	12.6	2.5	8	10.9	2.8	1.6	13	0.23	10	11.5	3.2	17	13.9	8.6	0.71	25	0.41
Attendance in territory ^c																											
Nestlings < 21 days old																											
Males	9	30.2	5.2	4	27.1	9.6	0.61	11	0.45	8	42.4	9.6	7	39.2	11.4	0.34	13	0.57	17	36.0	9.7	11	34.8	11.9	0.06	26	0.78
Females	4	46.0	5.4	9	46.9	10.8	0.26	11	0.88	7	59.0	11.4	8	61.7	12.8	0.18	13	0.68	11	54.3	11.4	17	53.9	13.7	0.01	26	0.94
Nestlings ≥ 21 days old																											
Males	9	30.0	13.7	2	27.1	11.5	--	--	--	8	40.9	5.4	7	35.4	10.9	1.6	13	0.23	17	35.1	11.8	9	33.6	10.9	0.1	24	0.75
Females	2	32.2	23.5	9	39.8	15.5	--	--	--	7	54.7	7.8	8	47.3	9.6	2.6	13	0.13	9	49.7	14.6	17	43.4	13.3	1.3	24	0.27

^a Nesting success comparison made using Likelihood ratio G^2_{adj} , all other comparisons made using one-way analysis of variance with group degrees of freedom=1.^b Young fledged per pair does not include successful pairs where fledge counts were incomplete and therefore probably underestimates actual productivity. See Lehman et al. (this volume) for unbiased estimates of productivity in 1992.^c Attendance means are the square root of the arcsine of the percent time spent at the nest or in the territory.

their transmitter and harness and picked at their bands, but quickly resumed courtship, incubation, and brood-rearing activities. Combining 1991 and 1992 observations, 7 instrumented falcons copulated, and 16 returned to their scrapes within 1 hr of release. One instrumented female received a prey item from her mate, and 1 instrumented male delivered prey to his mate during this time. On the day after instrumentation we observed all birds engaged in breeding activities (courtship, copulation, incubation, brood-rearing, or patrolling their territories). Capture and radio-marking did not appear to reduce a falcon's motivation to pursue prey as 1 female was recaptured stooping a rock dove (*Columba livia*) 1 day after initially being fitted with a transmitter.

Instrumented falcons did not have significantly lower fledging success than non-instrumented control birds (Table 2). The lack of an effect of instrumentation on productivity was exemplified in 1992 at 1 territory where the female still carried a transmitter attached in 1991 and the male wore a transmitter attached in 1992 (Fang Downstream). This pair had the highest productivity (6 fledglings) of any pair monitored in 1992.

The trend observed in 1991 for pairs that included females with transmitters to exhibit the highest rates of nest failure was not confirmed in 1992. Of the 4 pairs that failed in 1992, 3 had instrumented males. Combining 1991 and 1992, the difference in failure rate with respect to the sex of the instrumented bird was not significant ($G^2_{(1)} = 1.17, P = 0.28$). The lack of failures attributable to radio-tagged females in 1992 may have resulted because few females were captured before incubation. Three females

were caught during this time, and none failed (the nesting attempt of 1 of 8 males captured prior to incubation failed). We suspected 1 site with a radio-tagged female failed early (Swan I Draw Mouth), but later determined that it was successful. This female may have failed and then re-nested successfully. Eight females were caught later in the nesting cycle, and only 1 of their nesting attempts failed (2 of 9 nesting attempts of males caught at this time failed). One site with a radio-tagged female (Beercase Downstream) was excluded from the above analysis because its productivity was not confirmed.

Prairie falcons with transmitters and those without transmitters (those paired to radio-tagged mates) provisioned their nestlings at similar rates (Table 2). In 1992, regardless of nestling age, prey delivery rate was not associated with the presence of a transmitter for either males or females (although in 1992, prey delivery rates to nestlings < 21 days old tended to be higher by instrumented females than rates by non-instrumented females; Table 2).

In 1992, prairie falcons spent similar proportions of their time at their scrapes and in their territories regardless of being radio-tagged. Lack of a significant influence of instrumentation on attendance was evident in most analyses of the 1991-1992 combined data (Table 2).

Radio-tagged falcons and control falcons reared nestlings of similar weight (Table 2). Nestlings continued to fall into 2 mutually exclusive groups defined by foot pad length, therefore we divided nestlings into large (pads > 86 mm, presumably female) and small (pads < 86 mm, presumably male) categories and analyzed weight differences

(adjusted for crop fullness) within each group controlling for length of seventh primary and brood size. Both large nestlings and small nestlings reared by radio-tagged birds and untagged birds had similar weights in 1992 and in 1991-1992 combined years.

General patterns of activity.--Weather influenced the movement (and/or our ability to detect movement) of radio-tagged falcons. The number of birds contacted and number of fixes obtained at receiver sites increased as temperature increased (Fig. 2a,b; contacts: $r = 0.16$, $n = 2,846$, $P < 0.001$; fixes: $r = 0.16$, $n = 2,846$, $P < 0.001$). These measures of falcon activity increased then decreased as wind speed increased (Fig. 2c,d; curvilinear regression: contacts: $R = 0.18$, $n = 2,846$, $P < 0.001$; fixes: $R = 0.17$, $n = 2,846$, $P < 0.001$).

In 1992, as in 1991, falcons were more abundant around receiver sites west of the OTA than around sites inside the OTA. This result, however, was not uniform through the season or through a day (Fig. 3). There was an interaction between the season of tracking and location of the receiver position with respect to the OTA (2-way interaction: multivariate $F_{(2,10)} = 8.7$, $P = 0.006$) and the number of fixes $< 1,000$ ha per hr (2-way interaction: multivariate $F_{(2,10)} = 12.0$, $P = 0.002$). Activity was always greater around sites west of the OTA than around sites in the OTA, but this difference became accentuated as the season progressed (Fig. 3). The number of fixes obtained throughout the course of a day also varied between sites in the OTA and sites west of the OTA; fixes steadily increased with time west of the OTA, but leveled off or decreased in the afternoon at sites in the

OTA (2-way interaction: multivariate $F_{(2,10)} = 13.1$, $P = 0.002$).

Viewing the number of contacts and fixes at sites in the OTA versus west of the OTA with respect to temperature and wind speed simultaneously, reveals that falcons were most active at intermediate wind speeds and moderate to warm temperatures (Fig. 4). Moreover, contacts and fixes were greatest west of the OTA regardless of prevailing weather conditions.

Combining results from 1991 and 1992 strengthens the result that activity was significantly higher west of the OTA than inside the OTA. We contacted more birds and obtained more fixes per hr at receiver positions west of the OTA than at positions inside the OTA. Fixes increased throughout the day more strongly at positions west of the OTA than at sites in the OTA (2-way interaction: $F_{(2,16)} = 8.1$, $P = 0.004$), and the greatest difference between OTA and western receiver positions occurs during season 2 (mid-May - mid-June; 2-way interaction: $F_{(2,16)} = 11.1$, $P = 0.001$). Contact rates vary in a similar way, except that the 3-way interaction between time, season, and location of receiver position is significant because differences between locations vary considerably throughout the day within each season ($F_{(4,14)} = 5.7$, $P = 0.006$). In particular, in seasons 1 and 2 contacts from receiver positions in the OTA versus west of the OTA diverge more in the morning than in the afternoon, but late in the season counts diverge more in the afternoon than in the morning.

A bimodal pattern was evident in hourly assessments of activity. The bimodal nature of activity patterns was most pronounced during June when falcon activity was highest

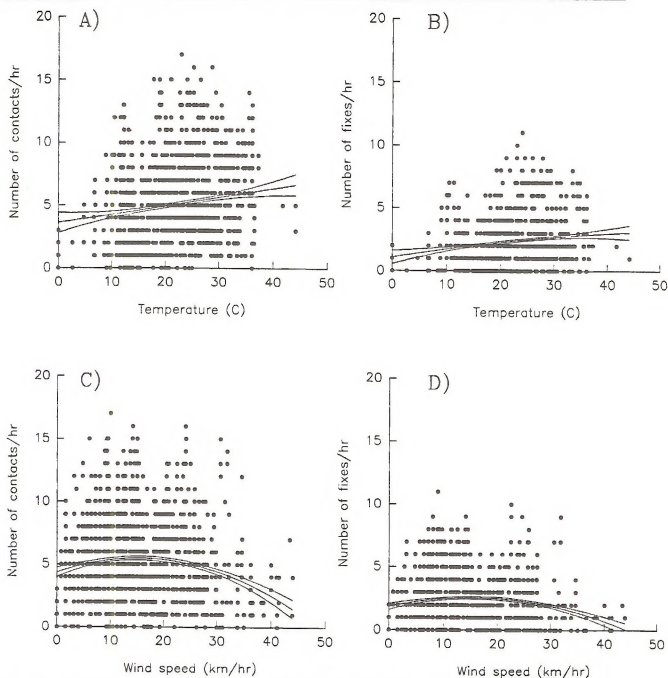


Fig. 2. Correlations between temperature and wind speed and the average number of radio-tagged falcons contacted per hr and the number of fixes < 1,000 ha obtained per hr from receiver sites west of the OTA (A, C) and in the OTA (B, D) in 1992. Weather was recorded with a portable weather station (see methods) located at a receiver site. Least squares estimated regression lines and associated 95% confidence intervals are plotted through points.

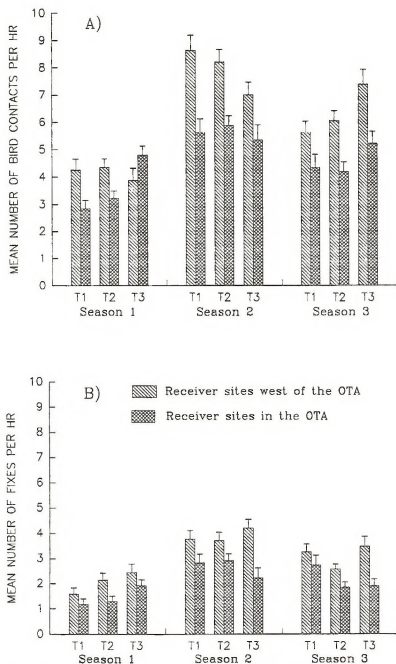


Fig. 3. Changes in the contact rate and number of fixes on radio-tagged falcons through the seasons (season 1 = 1 April - 15 May, season 2 = 16 May - 15 June, season 3 = 16 June - 1 August) and through the day (T1 = 0500-1000 hrs, T2 = 1100-1400 hrs, T3 = 1500-2100 hrs) in 1992. Means ± 1 SE are shown for 7 receiver sites in the OTA and 3 sites west of the OTA.

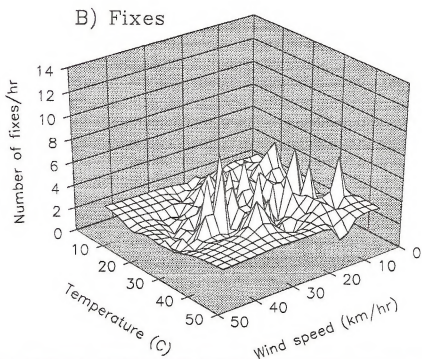
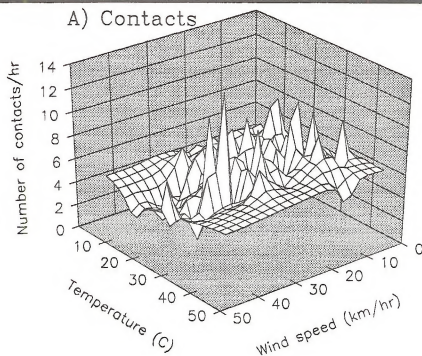


Fig. 4. The number of radio-tagged falcons contacted (A) and number of fixes with error ellipses < 1,000 ha obtained per hr (B) while radio-tracking throughout the study area in relation to temperature and wind speed in the tracking area in 1992.

and was evident at receiver positions in the OTA and those west of the OTA (Figs. 5,6).

Spatial use patterns and definitions of sampling adequacy.--Male and female falcons had different spatial use patterns, which influenced our ability to obtain location estimates from tracking zones on the benchlands above the canyon. As in 1991, females continued to be difficult to sample away from their aeries, which led to few fixes for females relative to males. Our observations of parental behavior in the territory, focal watches on poorly sampled females, and radio-tracking from a fixed-wing plane confirmed that the under-sampling of females is simply a result of their tendency to spend most of their time in their territory below the canyon rim. Females rarely ventured above the rim and into our tracking zones until the late post-fledging period, but males were above the rim throughout the nesting period (Dunstan et al. 1978). Therefore, we rarely obtained fixes on females early in the nesting cycle, but obtained fixes on males throughout the nesting period (Fig. 7a). This difference was highly significant ($\chi^2_{(4)} = 40.8, P < 0.001$).

Fixes on females late in the nesting period are critical to the delineation of their home ranges because they are important in defining the maximum area traversed by females. Sixty-four percent of fixes outside of the 95% core area for females were obtained during late brood-rearing and post-fledging (Fig. 7b). Late period fixes were less important to male home range delineation because only 37.8% of the outlying male fixes were obtained after fledging (Fig. 7b). The difference in timing of male and female excursions to the edge of their home ranges was significant ($\chi^2_{(4)} = 9.5, P = 0.05$).

Differences in male and female spatial use patterns led us to reappraise our definition of an "adequately sampled" home range. Adequately sampled males must have fixes from throughout the nesting cycle, but adequately sampled females should have their fixes concentrated in the last 2 stages of nesting (post fledging and fledgling dispersal). We considered males to be adequately sampled if they had at least 40 fixes, with some from every nesting period. This is slightly less than the 45-fix cutoff used in 1991, but incremental analysis indicates that an average of 85% of the space used by males is sampled in the first 40 fixes. We considered females to be adequately sampled if they had at least 25 fixes with at least 65% originating from the last 2 nesting periods. This is much more lenient than the 45-fix cutoff from 1991, but is justified because a randomization analysis indicates that 25 fixes define 70-80% of the space used by females.

Our new definitions of adequately sampled falcons are further justified because the resulting correlations between home range size and number of fixes used to calculate home range size are very weak. In 1992, 21 birds were adequately sampled, and the correlation between the 95% harmonic mean home range and the number of fixes was negligible ($r = -0.02, P = 0.92$). Similar results were obtained when the new definition was applied to the 1991 data ($r = 0.17, n = 20, P = 0.48$) and when 1991 and 1992 data were lumped ($r = 0.14, P = 0.40$). These correlations imply that less frequently sampled ranges were not unusually small, as one might expect if the intensity of sampling influenced the determination of home range.

Home range characteristics.--In 1992, we obtained 1,306 fixes with associated error

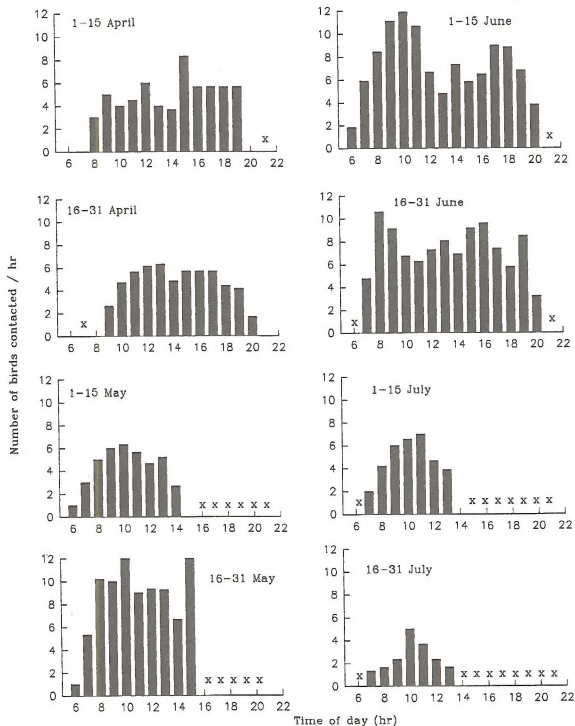


Fig. 5. Changes in radio-tagged falcon activity through the daylight hours and across the season at 3 receiver sites west of the OTA in 1992. An X indicates no observations were made during that hour.

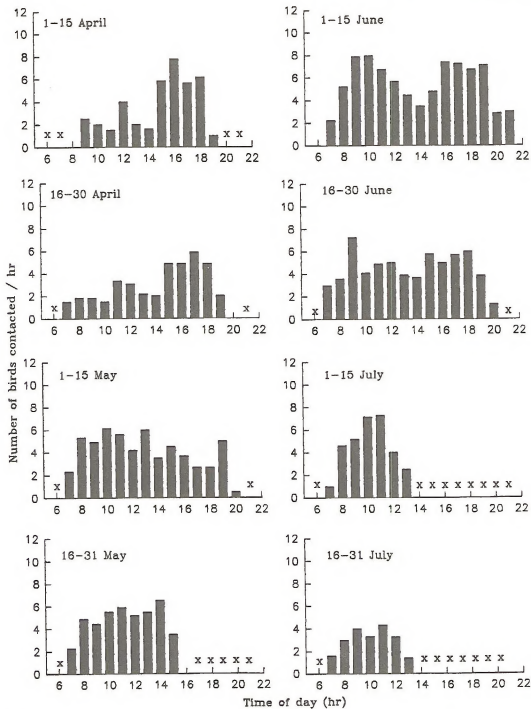


Fig. 6. Changes in radio-tagged falcon activity through the daylight hours and across the season at 10 receiver sites in the OTA in 1992. An X indicates no observations were made during that hour.

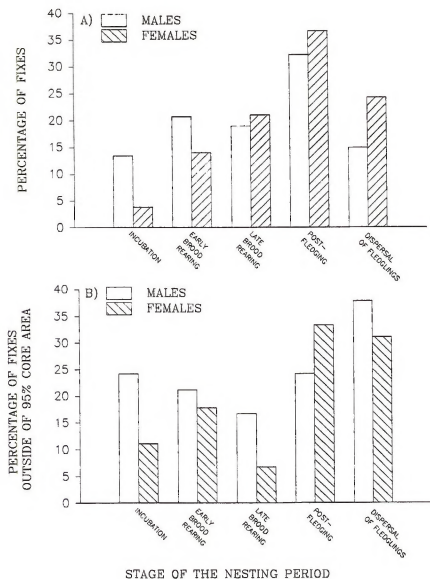


Fig. 7. Percentage of all location estimates (A) and excursive locations (B) obtained on radio-tagged falcons throughout the study area in relation to stage in the breeding cycle. Stage of breeding for each falcon was determined by back-dating from the age estimate at the time of banding. Early brood-rearing is the time from hatching to 20 days post hatch. Late brood-rearing includes nestlings 21-40 days old. Post-fledging is the first month after fledging. Fledgling dispersal is > 1 month post-fledging.

ellipses < 1,000 ha that met the criterion that 2 fixes not be taken on the same bird within 30 min. Maps of home ranges of falcons adequately sampled in 1992 are shown in Figs. 8-12. As discussed in Marzluff et al. (1991), home ranges are depicted as the area including 95% of the fixes around the harmonic mean. We present several other measures of home range size, travel distance and home range shape in Table 3.

Successful breeders, failed breeders, and non-breeders differed in their ranging habits. Lumping data from 1991 and 1992, provided data on 7 adequately sampled falcons that failed to fledge young, 33 falcons that nested successfully, and 1 female that was unpaired. Failed breeders tended to range to farther maximum distances from their nests than did successful breeders ($\bar{x}_{\text{failed}} = 20,863$ m, $n = 5$, $SD = 5,449$, $\bar{x}_{\text{successful}} = 15,217$ m, $n = 33$, $SD = 6,729$; $F_{(1,36)} = 3.2$, $P = 0.08$). Mean travel distance from the nest and home range size were similar between successful and failed breeders (mean travel distance: $\bar{x}_{\text{failed}} = 5,438$ m, $n = 5$, $SD = 1,272$, $\bar{x}_{\text{successful}} = 5,747$ m, $n = 33$, $SD = 2,913$; $F_{(1,36)} = 0.05$, $P = 0.82$; 95% core range size: $\bar{x}_{\text{failed}} = 12,840$ ha, $n = 7$, $SD = 7,662$, $\bar{x}_{\text{successful}} = 15,980$ ha, $n = 33$, $SD = 11,647$; $F_{(1,36)} = 0.14$, $P = 0.72$). Home range size of the 1 female that did not breed was the largest we have recorded for a female (29,163 ha). These differences in ranging behavior with respect to breeding success were accounted for in subsequent analyses by excluding the female non-breeder, and we confirmed that differences in ranging habits associated with military training remained unchanged even when only successful breeders were included in the analysis.

Adequately sampled falcons ranged farther from their nests in 1991 than in 1992 (Fig.

13a). Falcons ranged an average of 7,369 m ($SD = 2,892$) from their nests in 1991, and 4,210 m in 1992 ($SD = 1,485$). The average maximum distance these birds traveled from their nests was 19,129 m ($SD = 7,406$) in 1991, and 13,924 ($SD = 4,070$) in 1992. Their average home range size (using the 95% use area around the harmonic mean) was 17,885 ha ($SD = 12,209$) in 1991 and 13,747 ha ($SD = 9,816$) in 1992. These differences are highly significant (year effect in MANOVA testing year, sex, and location differences in all 3 ranging variables simultaneously: multivariate $F_{(3,28)} = 14.1$, $P < 0.001$), and evident even if only successful breeders are analyzed (multivariate $F_{(3,23)} = 14.1$, $P < 0.001$). Home ranges defined by cluster analysis also were larger in 1991 ($\bar{x} = 9,948$ ha, $SD = 3,857$) than in 1992 ($\bar{x} = 6,909$ ha, $SD = 5,436$; $F_{(1,32)} = 4.0$, $P = 0.055$).

The average differences in home range size from 1991 to 1992 are mirrored in a smaller subset of our data taken from nesting areas monitored in both years. By chance, we radio-tagged falcons at the same nesting area ($n = 2$) or at nesting areas separated by at most 1 other nesting area ($n = 6$) in 1991 and 1992. Harmonic mean home ranges were greater in 1991 than in 1992 regardless of whether the radio-tagged bird was a male in both years (\bar{x} difference subtracting 1992 from 1991 = 9,214 ha, $n = 2$, $SD = 2,110$), a female in both years (\bar{x} difference = 5,598 ha, $n = 3$, $SD = 9,978$), or a male in 1992 and a female in 1991 (\bar{x} difference = 1,770 ha, $n = 3$, $SD = 5,449$).

Males and females had significantly different ranging habits (Fig. 13b). Males had larger home ranges than females in 1991 and 1992, and traveled farther from their nests than females in 1991. Combining 1991 and 1992,

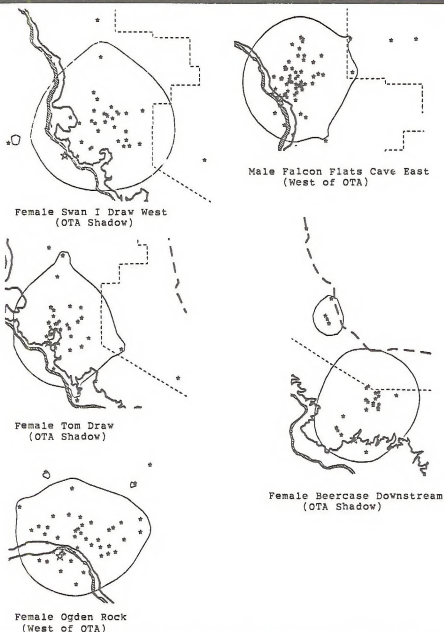


Fig. 8. Spatial use patterns of 21 radio-tagged prairie falcons in 1992. Each bird was adequately sampled (see methods). Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation; north is oriented to the top of the page. Each map is drawn to the same scale (1 : 350,000).

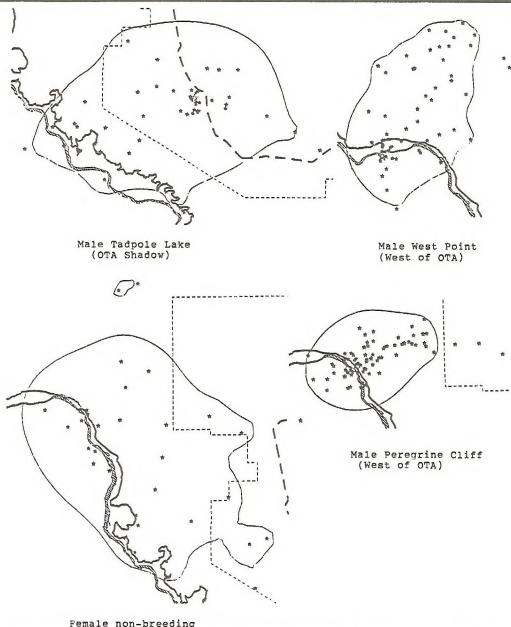


Fig. 9. Spatial use patterns of 21 radio-tagged prairie falcons in 1992. Each bird was adequately sampled (see methods). Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation; north is oriented to the top of the page. Each map is drawn to the same scale (1 : 350,000).

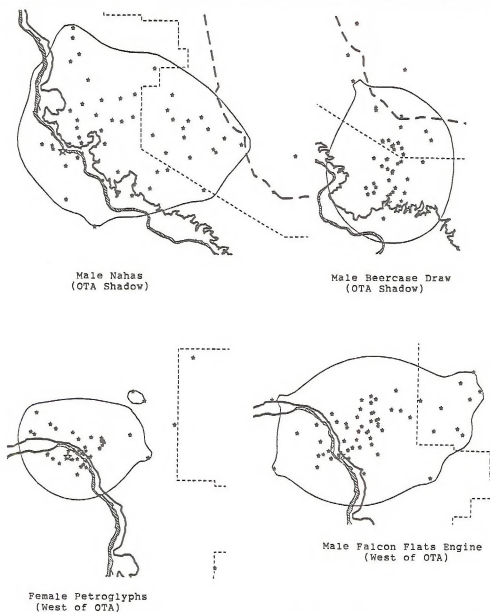


Fig. 10. Spatial use patterns of 21 radio-tagged prairie falcons in 1992. Each bird was adequately sampled (see methods). Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation; north is oriented to the top of the page. Each map is drawn to the same scale (1 : 350,000).

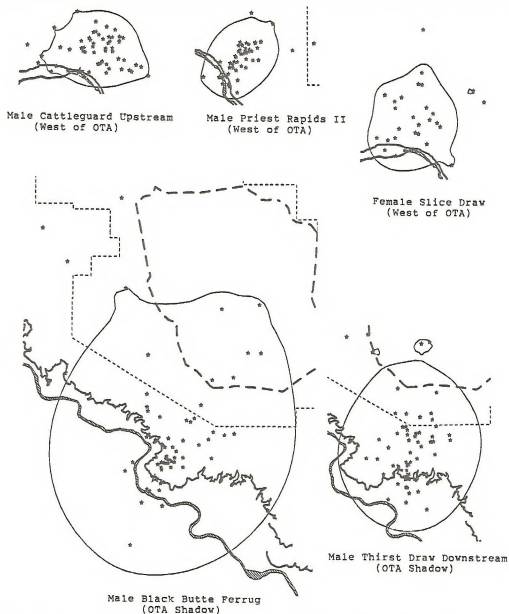


Fig. 11. Spatial use patterns of 21 radio-tagged prairie falcons in 1992. Each bird was adequately sampled (see methods). Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation; north is oriented to the top of the page. Each map is drawn to the same scale (1 : 350,000).

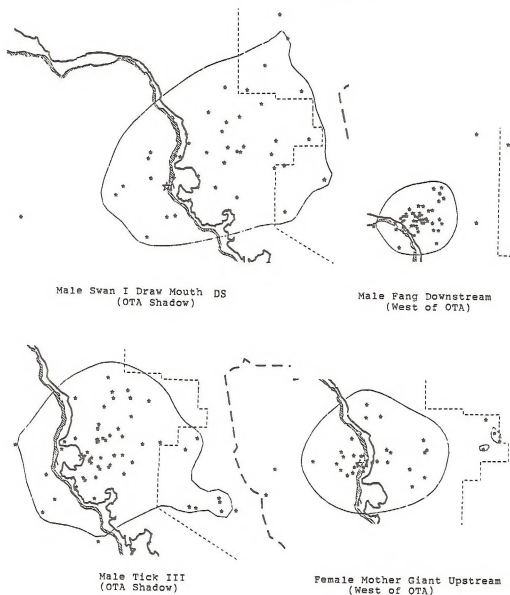


Fig. 12. Spatial use patterns of 21 radio-tagged prairie falcons in 1992. Each bird was adequately sampled (see methods). Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation; north is oriented to the top of the page. Each map is drawn to the same scale (1 : 350,000).

Table 3. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1992. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

Nesting ^a Area	Sex	OTA	N	Mean distance from:				Max distance from:			Harmonic Mean Home Range				Convex Polygon Home Range			
				Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%
Pcliff	M	n	86	2,726	940	2,673	1,143	12,770	13,770	11,350	27,889	6,992	4,768	1,404	7,704	3,411	1,464	592
Wpt	M	n	68	5,376	818	4,645	1,057	13,490	12,440	9,115	16,029	12,527	10,412	2,721	11,560	9,128	6,318	1,773
Tick3	M	y	66	4,855	946	4,332	674	16,530	15,930	13,610	38,252	17,661	15,342	2,588	18,710	14,430	4,812	1,509
FngDS	M	n	64	2,136	597	1,592	1,469	11,410	10,010	9,695	14,796	3,503	2,182	471	5,433	1,541	499	311
FFCE	M	n	63	3,014	58	2,201	2,208	12,600	10,450	10,370	16,635	7,746	4,047	667	6,648	2,963	1,405	843
BBFer	M	y	63	5,543	761	4,953	1,448	24,120	22,880	20,430	61,900	41,796	22,220	2,676	31,860	10,780	3,902	1,663
TDOS	M	y	63	3,962	1,264	3,168	1,110	13,070	12,070	10,620	20,002	14,392	7,219	1,419	9,488	4,672	2,876	1,748
FFE	M	n	60	4,556	1,781	3,625	4,154	13,370	9,488	10,090	18,226	16,621	12,890	2,040	12,050	9,200	2,980	2,035
Nahas	M	y	59	7,307	2,998	5,850	880	19,900	19,310	14,450	41,656	22,855	19,028	4,956	24,420	17,090	11,900	6,953
CGUS	M	n	58	3,173	557	2,252	2,533	5,872	7,299	5,959	6,773	4,510	4,170	952	3,618	2,798	1,763	1,246
BcsDw	M	y	51	4,130	1,231	3,198	1,478	15,550	14,520	12,190	22,273	11,710	5,512	1,248	8,606	4,727	2,704	1,294
PrRp2	M	n	51	2,514	900	1,693	2,933	8,206	6,176	6,277	7,590	3,414	1,843	416	3,103	1,164	900	718
OgR	F	n	48	3,482	666	2,894	1,250	10,960	9,924	8,522	12,528	6,693	5,526	1,724	7,748	4,474	2,383	1,461
Sw1DW	F	y	44	5,444	785	2,974	3,336	11,950	8,616	7,316	10,801	6,608	6,215	1,596	8,550	5,145	3,222	2,475
TdpLk	M	y	44	4,854	1,149	5,064	1,133	15,150	15,130	13,180	35,023	24,061	18,080	3,064	20,830	16,950	5,990	1,205
Ptgrl	F	n	43	2,930	882	2,710	1,389	13,680	12,490	11,790	17,722	7,872	7,223	814	7,691	3,041	1,213	629
S1DMD	M	y	43	7,260	2,946	5,636	9,715	17,650	19,310	17,600	49,505	23,689	19,486	6,034	24,320	18,480	8,087	5,825
TomDw	F	y	39	2,855	1,088	2,389	1,805	11,550	11,370	10,520	14,098	7,240	5,887	608	7,446	2,313	830	408
MGUp	F	n	37	3,447	1,013	3,536	567	12,190	11,640	9,982	11,567	10,269	5,789	996	7,006	4,052	2,058	398
HHGt	M	n	37	7,748	3,234	5,699	6,896	25,830	19,940	20,240	61,565	20,016	18,237	5,581	25,150	14,010	9,060	7,034
Sld2	M	y	33	5,261	1,522	2,808	5,004	11,950	9,069	9,071	14,739	11,553	7,074	1,180	9,910	3,751	2,711	2,063
Bptus	M	y	33	7,980	2,625	5,589	11,272	18,440	13,820	11,920	25,896	15,793	13,284	3,374	18,720	11,460	9,434	4,567
Unkn ^b	F		32	—	2,874	7,399	—	—	20,650	15,510	31,974	29,163	25,324	6,572	28,160	23,350	10,050	4,161
BcsDw	F	n	30	3,721	1,594	2,919	132	10,520	10,490	7,727	9,341	5,466	5,050	1,153	5,500	3,138	2,133	966
SldDS	F	y	26	5,138	968	3,750	3,487	18,470	15,970	14,300	21,144	7,373	4,367	639	6,587	3,378	1,097	897
HndDw	F	y	23	5,354	874	3,662	5,857	11,690	6,997	7,535	8,387	5,484	5,340	1,152	7,424	5,829	3,581	1,970
Sw1DM	F	y	17	6,257	2,148	3,648	3,644	11,530	8,200	6,966	4,773	3,948	3,340	978	7,239	5,257	3,143	2,198
HlvSp	F	n	15	4,384	1,309	4,201	0	11,190	11,190	11,310	10,910	8,766	5,555	1,078	8,200	5,237	2,549	586
MssFc	F	y	11	1,842	700	1,922	0	6,196	6,196	5,241	1,038	515	515	139	1,262	673	218	97
DcdPt	F	n	11	9,748	3,628	6,814	5,452	35,750	30,740	27,370	23,722	7,980	7,980	2,999	14,320	4,030	3,159	1,704
OgGE	F	n	8	2,265	475	2,304	1,135	9,284	8,260	8,109	1,629	427	156		671	164	132	64

^a Nesting areas abbreviated as follows: Pcliff-Peregrine Cliff, Wpt-West Point, Tick3-Tick III, FngDS-Fang Downstream, FFCE-Falcon Flats Cave East, BBFer-Black Butte Ferrug, TDOS-Thirst Draw Downstream, FFE-Falcon Flats Engine, Nahas-Nahas, CGUS-Cattleguard Upstream, BcsDw-Bearcase Draw, PrRp2-Priest Rapids II, OgR-Ogden Rock, Sw1DW-Swan I Draw West, TdpLk-Tadpole Lake, Ptgrl-Petroglyphs, S1DMD-Swan I Draw Mouth Downstream, TomDw-Tom Draw, MGUp-Mother Giant Upstream, HHGt-Hell Hole Gate, Sld2-Slice Draw, BcsDS-Bearcase Downstream, HlvSp-Halverson Spring, MssFc-Massacre Face, DcdPt-Dedication Point, OgGE-Ogden GE77.

^b This individual was trapped in the Red Trail nest area but was not a member of the Red Trail nesting pair and never established a nesting territory.

Table 3. (Continued.) Home range characteristics of paired prairie falcons determined from radiotelemetry in 1992. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr= sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n/2d^{-1}$), D=dispersion, SK=skewness, K=kurtosis, Sp=spread.

Nesting Area *	Sex	OTA	N	Home Range Shape						No. Locations inside:	
				Maximum Polygon width	Harmonic Mean				Sp	OTA(%)	Range Rd(%)
					Hr	D	Sk	K			
Pclff	M	n	86	18,270	951.6	3.3	9.5	6.4	1,832	3 (3)	0 (0)
Wpt	M	n	68	16,910	832.7	3.7	15.7	11.6	2,683	0 (0)	0 (0)
Tick3	M	y	66	22,320	981.0	3.5	8.9	10.4	2,815	8 (15)	2 (3)
FngDS	M	n	64	13,500	606.5	2.1	1.7	4.0	1,151	1 (2)	0 (0)
FFCE	M	n	63	13,550	59.4	7.4	44.4	112.8	903	4 (5)	0 (0)
BBFer	M	y	63	29,720	773.5	3.8	14.4	12.4	2,501	10 (16)	6 (10)
TDDS	M	y	63	16,350	1,284.9	1.7	2.2	3.1	2,371	13 (21)	2 (3)
FFE	M	n	60	18,870	1,811.7	1.4	0.6	2.3	2,988	9 (5)	0 (0)
Nahas	M	y	59	23,030	3,050.6	1.6	2.7	2.8	5,080	17 (29)	1 (2)
CGUS	M	n	58	10,680	567.2	5.5	17.5	17.7	1,836	0 (0)	0 (0)
BcsDw	M	y	51	16,930	1,255.6	3.5	7.7	6.4	2,421	19 (37)	3 (6)
PrRp2	M	n	51	9,982	918.0	1.4	1.6	2.1	1,340	1 (2)	0 (0)
OgR	F	n	48	12,490	680.9	4.7	10.6	17.0	2,442	0 (0)	0 (0)
Sw1DW	F	y	44	12,900	903.3	3.4	6.2	10.3	2,429	1 (2)	0 (0)
TdpLk	M	y	44	25,360	1,175.8	2.0	3.7	4.9	2,914	32 (73)	10 (23)
Ptgrl	F	n	43	15,240	903.7	2.0	2.0	4.1	1,892	2 (5)	0 (0)
S1DMD	M	y	43	28,140	3,016.2	1.6	1.0	2.8	5,177	6 (19)	0 (0)
TomDw	F	y	39	15,710	1,117.6	1.2	0.9	1.8	1,682	2 (5)	0 (0)
MGUp	F	n	37	16,050	1,041.3	1.7	2.9	3.6	2,197	1 (3)	0 (0)
HHGt	M	n	37	30,790	3,324.4	1.0	0.3	1.6	5,066	7 (15)	1 (3)
Skd2	M	y	33	16,810	1,570.3	1.0	0.4	1.5	2,456	1 (3)	0 (0)
Bpus	M	y	33	20,060	2,708.0	2.2	4.3	3.9	4,815	13 (38)	0 (0)
Unkn ^b	F		32	28,000	2,967.3	1.6	2.9	3.3	6,064	5 (16)	0 (0)
SlDw	F	n	30	11,910	1,649.4	2.2	3.7	3.5	2,683	0 (0)	0 (0)
BcsDS	F	y	26	19,780	1,007.5	1.2	2.2	2.1	1,768	6 (24)	1 (4)
HndDw	F	y	23	12,770	914.6	3.3	5.7	10.4	2,908	11 (50)	1 (5)
Sw1DM	F	y	17	12,630	2,283.2	0.9	0.8	1.4	3,555	0 (0)	0 (0)
HlvSp	F	n	15	20,220	1,403.5	1.8	2.6	4.1	3,188	0 (0)	0 (0)
MssFc	F	y	11	7,004	770.7	1.3	1.6	2.4	1,489	0 (0)	0 (0)
DdcPt	F	n	11	35,750	3,991.0	0.6	0.6	0.8	5,174	3 (30)	0 (0)
OgGE	F	n	8	10,690	543.2	1.9	0.5	3.7	1,078	0 (0)	0 (0)

* Nesting areas abbreviated as follows: Pclff-Peregrine Cliff, Wpt-West Point, Tick3-Tick III, FngDS-Fang Downstream, FFCE-Falcon Flats Cave East, BBFer-Black Butte Ferrug, TDDS-Thirst Draw Downstream, FFE-Falcon Flats Engine, Nahas-Nahas, CGUS-Cattleguard Upstream, BcsDw-Beercase Draw, PrRp2-Priest Rapids II, OgR-Ogden Rock, Sw1DW-Swan 1 Draw West, TdplLk-Tadpole Lake, Prgl-Petroglyphs, S1DMD-Swan 1 Draw Mouth Downstream, TomDw-Tom Draw, MGUp-Mother Giant Upstream, HHGt-Hell Hole Gate, SlDw-Slice Draw, BcsDS-Beercase Downstream, HlvSp-Halverson Spring, MssFc-Massacre Face, DdcPt-Dedication Point, OgGE-Ogden GE77.

^b This individual was trapped in the Red Trail nest area but was not a member of the Red Trail nesting pair and never established a nesting territory.

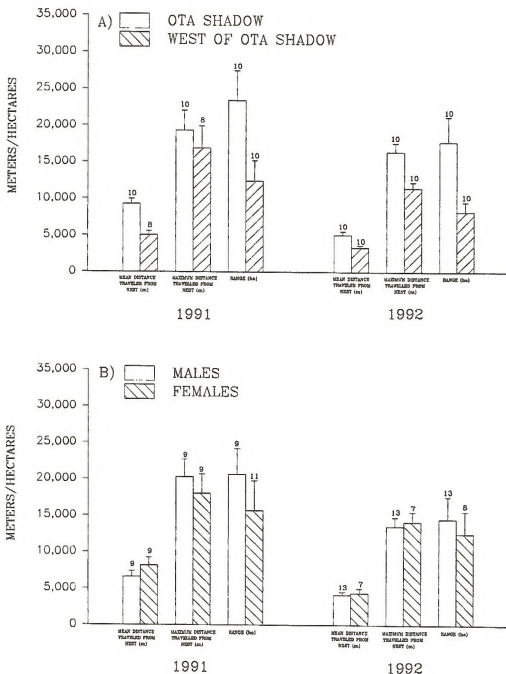


Fig. 13. Ranging habits of 20 radio-tagged prairie falcons in 1991 and 21 falcons in 1992. Area and distances traveled are contrasted with respect to the aerie location (OTA shadow versus west of the shadow) and sex. Home ranges are 95% core areas around the harmonic mean. Averages \pm 1 SE are plotted.

males ranged over significantly larger areas than females (sex effect in MANOVA testing year, sex, and location differences in all 3 ranging variables simultaneously: multivariate $F_{(3,28)} = 4.6$, $P = 0.01$). This result was robust when only successful breeders were analyzed (multivariate $F_{(3,23)} = 3.0$, $P = 0.05$).

Falcons nesting in the OTA shadow ranged over significantly larger areas than falcons nesting west of the shadow (Fig. 13a). This difference was consistent in 1991 and 1992, and highly significant in the analysis of data combined from 1991 and 1992 (location effect in MANOVA testing year, sex, and location differences in all 3 ranging variables simultaneously: multivariate $F_{(3,28)} = 9.8$, $P < 0.001$). This difference remained significant when only successful breeders were analyzed (multivariate $F_{(3,23)} = 8.5$, $P = 0.001$). However, the difference in ranging habits between falcons in the OTA and west of OTA was greater in 1991 than in 1992 (2-way interaction between location and year: multivariate $F_{(3,23)} = 3.2$, $P = 0.04$). Falcons nesting in the OTA shadow had home ranges defined by cluster analysis that were over twice as large as ranges occupied by falcons west of the OTA ($\bar{x}_{OTA} = 11,154$ ha, SD = 6,842; $\bar{x}_{west\ of\ OTA} = 5,490$ ha, SD = 3,857; $F_{(1,32)} = 8.1$, $P = 0.008$).

Internal anatomy of home ranges.--Prairie falcons had distinct core use areas within their large home ranges. In 1991 and 1992, 95% of the telemetry locations on falcons were in only slightly over 50% of the total home range area (1991: $\bar{x} = 56.6\%$, $n = 20$, SD = 23.4; 1992: $\bar{x} = 55.5\%$, $n = 21$, SD = 17.7). Eighty-five percent of the fixes were in only slightly over 25% of the total home range area (1991: $\bar{x} = 24.9\%$, $n = 20$, SD = 11.0; 1992: $\bar{x} = 30.2\%$, $n = 21$, SD = 12.4).

The occurrence of core areas was indicated by the small percentage of the total range area that included these large percentages of the total fixes. Core areas were commonly distributed among several activity centers. Cluster analysis identified 1 - 5 activity centers in the 95% cores and 1 - 8 centers in the 85% cores.

Ranges with well-defined core areas had more activity centers than ranges with poorly defined core areas. Ranges with well-defined core areas included a high percentage of fixes in a small percentage of the total space used by the falcon. Ranges with the most clearly defined core areas had the most activity centers (number of activity centers correlated with: % of area including 95% of fixes: $r = -0.60$, $n = 41$, $P < 0.001$; % of area including 85% of fixes: $r = -0.46$, $n = 41$, $P = 0.002$).

Large home ranges did not have more distinct cores or more activity centers than small home ranges. Correlations between home range size and the percent of the total area delineated by 95% and 85% of the fixes were generally weak or not significant (harmonic mean home range size correlated with % of total area including: 95% of fixes: $r = -0.05$, $n = 41$, $P = 0.74$; 85% of fixes: $r = -0.12$, $n = 41$, $P = 0.46$). Likewise, correlations between home range size and the number of activity centers defined within the area encompassing 95% and 85% of the fixes were not significant (harmonic mean home range size correlated with number of activity centers in area including: 95% of fixes: $r = 0.11$, $n = 41$, $P = 0.48$; 85% of fixes: $r = -0.01$, $n = 41$, $P = 0.95$).

The distinctiveness of core areas did not differ between males and females, between falcons nesting in the OTA shadow versus

west of the shadow, or between years. All factors in a 3-way MANOVA testing for differences in the percentage of the total range incorporating 95% and 85% of the fixes were not significant (multivariate F -tests of main effects: effect of sex: $F_{(2,32)} = 2.4$, $P = 0.11$; effect of nest location: $F_{(2,32)} = 0.4$, $P = 0.65$; effect of year: $F_{(2,32)} = 2.3$, $P = 0.12$).

Falcons had ranges with more activity centers in 1991 than in 1992. This was especially conspicuous within the 85% core area (1991: $\bar{x} = 3.2$ activity centers, $SD = 2.5$; 1992: $\bar{x} = 2.0$ activity centers, $SD = 1.0$), but also occurred in the 95% core area (1991: $\bar{x} = 1.8$ activity centers, $SD = 0.8$; 1992: $\bar{x} = 1.7$ activity centers, $SD = 1.0$). Analysis of both measures of activity centers simultaneously between years was highly significant (multivariate $F_{(2,32)} = 6.6$, $P = 0.004$). The number of activity centers did not differ between males and females (multivariate $F_{(2,32)} = 2.4$, $P = 0.11$) or between birds nesting in the OTA versus west of the OTA (multivariate $F_{(2,32)} = 0.4$, $P = 0.65$).

Travel distances from aeries.--The distance falcons traveled from their aeries depended upon location of the aerie, sex of the radio-tagged bird, and stage of the nesting cycle (Fig. 14; 3-way interaction $F_{(4,1253)} = 7.2$, $P < 0.001$). During incubation, males and females made occasional distant forays from their aeries. The average travel distance was therefore usually greatest for males and females at this time. However, females in the OTA shadow traveled exceptional distances during incubation. Males, regardless of the location of their nest, abruptly reduced their travel distance during early brood rearing. However, as the nesting season progressed, male travel distances

varied depending upon the nest's location; males in the OTA shadow increased travel distances, but males west of the shadow traveled slightly farther during late brood-rearing and then decreased travel distance. Females in the shadow and west of the shadow remained relatively close to their aeries during brood-rearing and increased their travel significantly after their fledglings became independent.

Military activity on training ranges influenced average travel distance significantly, and depended on the location of the aerie (Fig. 15). Falcons nesting in the OTA shadow ranged farther from their nests on training days than on non-training days. This was most striking for females which ranged nearly 2 km farther on firing than non-firing days. In contrast, falcons nesting west of the OTA showed little difference in travel distances with respect to training and actually stayed closer to their aeries on training days than non-training days. The interaction between aerie location and training activity was significant in the 3-factor ANOVA controlling for breeding stage (2-way interaction: $F_{(1,1264)} = 4.9$, $P = 0.03$).

Increased travel by falcons nesting in the OTA shadow during periods of military training was consistent throughout the season and not solely a response to the intensive use of the OTA during Operation Bold Shift. We conducted an analysis of travel distance to compare responses of pairs nesting in the OTA shadow and west of the shadow to training versus non-training days during Bold Shift versus during the rest of the season. There was no significant difference in travel distance during Bold Shift ($F_{(1,1265)} = 2.2$, $P = 0.14$). Falcons nesting in the OTA shadow and those nesting west of the

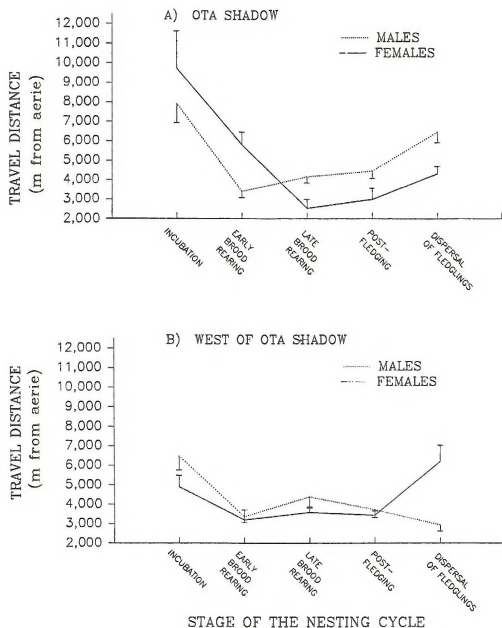


Fig. 14. Travel distance from the aerie by 30 prairie falcons radio-tagged in 1992. Male and female travel distances + 1 SE are plotted in respect to stage of the breeding cycle (see Fig. 7 for definition of stages). The non-breeding female is not included in this analysis.

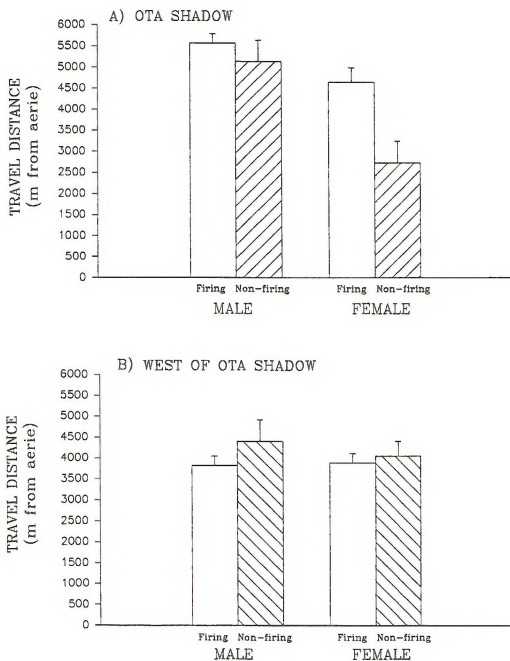


Fig. 15. Travel distance from the aerie by 30 prairie falcons (same as Fig. 14) on training and on non-training days.

shadow responded in similar ways to training during Bold Shift compared to during the rest of the season (3-way interaction between military activity, nest location and the occurrence of Bold Shift: $F_{(1,1265)} = 0.002, P = 0.96$).

Use of the OTA.--As in 1991, falcons tended to range northeast from their aeries toward the OTA, but because travel distances from aeries were less in 1992 than in 1991, use of the OTA was reduced in 1992. Eight falcons never entered the OTA during the 1992 season, and only 2 birds were located in the OTA on half or more of our samples (Table 3). Use of the impact area was minimal in 1992; only 9 falcons were located inside the OTA's Range Road, and only 1 bird was there more than 20% of time. This was the male from Tadpole Lake (Frequency 4085 in Table 3), the new nesting area found in the OTA just outside the Range Road. Reduced use of the OTA by raptors in 1992 approached significance in a MANOVA comparing the percent of fixes inside the OTA and the percent inside the range road between 1991 and 1992 (multivariate $F_{2,37} = 2.5, P = 0.09$).

In 1992, birds categorized as nesting in the newly defined OTA shadow were located inside the OTA boundaries ($\bar{x} = 22.6\%$, $SD = 21.4$, $n = 14$) more often than birds categorized as nesting west of the OTA ($\bar{x} = 3.8\%$, $SD = 5.3$, $n = 16$; $t = 3.4$, $df = 28$, $P = 0.002$). Reanalyzing the data from 1991 with respect to the new shadow boundaries supported this contention ($\bar{x}_{\text{shadow}} = 43.3\%$, $SD = 18.0$, $n = 14$, $\bar{x}_{\text{west of shadow}} = 8.5\%$, $SD = 7.3$, $n = 11$; $t = 6.0$, $df = 23$, $P < 0.001$).

Although average travel distances from aeries varied with military activity on the firing ranges, falcons did not appear to avoid

the OTA or the impact area on firing days. In 1992, falcons nesting in the OTA shadow were inside the OTA 28% of the time on non-training days. On training days, these birds were in the OTA 25% of the time. Likewise, 4.3% of fixes were inside the Range Road when training occurred on the ranges, and 4.8% of fixes were inside the Range Road when there was no training on the ranges. Overall, range activity and location of fixes with respect to the OTA were not associated for birds nesting in the OTA shadow ($\chi^2_{(2)} = 0.67, P = 0.72$). Falcons nesting west of the OTA were only located inside the OTA 4.5% of the time and their use of the OTA was also unrelated to range activity ($\chi^2_{(2)} = 3.8, P = 0.15$).

Association with agricultural fields.--We often observed falcons near agricultural fields apparently preying upon abundant Townsend's ground squirrels along field edges. Falcons nesting west of the OTA had the greatest access to fields, and accordingly, they included more agricultural fields in their home ranges than falcons nesting in the OTA shadow (Fig. 16). Males tended to be associated with agricultural fields more than females, and 7 of 14 males increased use of fields from April-May to June-August (Fig. 16). Females used fields more commonly early in the season and reduced their use late in the season when they explored larger areas; 0 of 7 females increased use of fields from April-May to June-August (Fig. 16).

Is ranging behavior inferred by telemetry comparable to that determined by direct observation?--The strong relationship in 1991 between ranging habits of falcons determined by telemetry and by direct surveillance of aeries was lessened in 1992. Wide ranging birds tended to be seen in their territories less than close ranging birds.

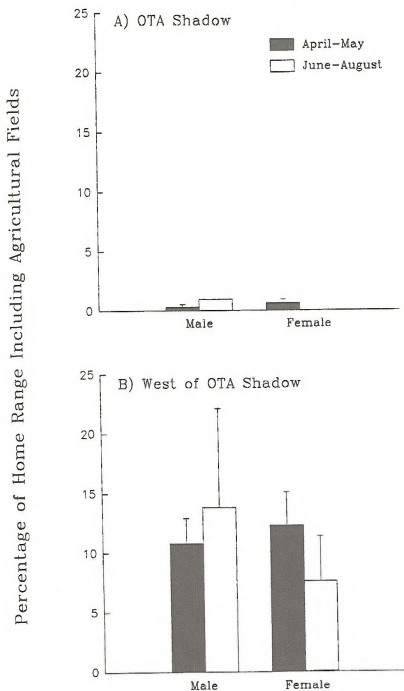


Fig. 16. Percentage of prairie falcon 95% harmonic mean home ranges that include agricultural fields in 1992. Eight males and 4 females in the OTA shadow, and 6 males and 3 females west of the shadow were sampled. Home ranges early (April-May) and late (June-August) in the season are contrasted.

However, correlations between the percent of time a falcon was observed in its territory and the maximum distance a falcon traveled from its nest, the mean distance traveled from its nest, and home range were all weak and not significant (all P 's > 0.30). Lumping 1991 and 1992 produced significant correlations between the percent of time a falcon was seen in its territory and maximum travel distance from the nest ($r = -0.76$, $n = 19$, $P < 0.001$), mean distance from the nest ($r = -0.60$, $n = 19$, $P = 0.01$), and home range size ($r = -0.64$, $n = 19$, $P = 0.003$).

Influence of ranging behavior on fledgling productivity.--Ranging habits appear to have little influence on a pair's productivity. As in 1991, the variation in the number of young fledged per pair was not significantly correlated with a bird's ranging habits in 1992 (correlating number of fledglings with: mean travel distance from the nest: $r = -0.63$, $n = 7$, $P = 0.13$; maximum travel distance from the nest: $r = -0.47$, $n = 7$, $P = 0.28$; home range size: $r = 0.09$, $n = 7$, $P = 0.86$) or with the percentage of times we recorded the bird inside the OTA boundaries ($r = -0.39$, $n = 7$, $P = 0.38$) or inside the Range Road ($r = -0.24$, $n = 7$, $P = 0.61$). Combining data from 1991 and 1992 also failed to produce any significant correlations between ranging behavior and productivity (all P 's > 0.22).

Dispersal of falcons from the study area.--Dispersal of adult falcons from the study area began 2 weeks earlier in 1992 (first departure on 23 June) than in 1991 (first departure 7 - 13 July). Over 33% of the falcons ($n = 11$) dispersed on or before 7 July 1992, the earliest dispersal date recorded in 1991. In 1992, dispersal continued through July and August, as it did

in 1991, but the overall temporal pattern of dispersal differed significantly between years (Fig. 17; comparing the number of dispersers per 2-week interval 23 July - 7 August: $\chi^2_{(2)} = 9.7$, $P = 0.008$). Four birds remained in the study area through September.

The trend observed in 1991 for birds nesting in the OTA shadow to remain in the study area longer than birds nesting west of the shadow was not supported in 1992 (comparing Julian dates of dispersal: $\bar{x}_{\text{shadow}} = 205.9$, $SD = 19.0$, $n = 14$, $\bar{x}_{\text{west of shadow}} = 199.1$, $SD = 21.3$, $n = 16$; $t = 0.90$, $df = 28$, $P = 0.37$) or when 1991 and 1992 were lumped and the 1992 shadow boundaries were used ($\bar{x}_{\text{shadow}} = 207.8$, $SD = 15.6$, $n = 25$, $\bar{x}_{\text{west of shadow}} = 200.9$, $SD = 18.3$, $n = 24$; $t = 1.4$, $df = 47$, $P = 0.16$). Hatch date and nesting success also were not correlated with dispersal date in 1992 (correlation with hatch date: $r = -0.10$, $n = 27$, $P = 0.62$; 1-way ANOVA comparing 25 successful and 4 unsuccessful pairs: $F_{1,27} = 0.09$, $P = 0.76$) or in the combined observations from 1991 and 1992 (correlation with hatch date: $r = 0.05$, $n = 43$, $P = 0.74$; 1-way ANOVA comparing 39 successful and 7 unsuccessful pairs: $F_{1,44} = 0.20$, $P = 0.66$).

Tracking falcons in the eastern study area.--We instrumented 1 male from a nesting area east of the OTA shadow (Rattlesnake Canyon) to determine the feasibility of tracking birds nesting in that portion of the study area. We received this male's signal from our eastern-most tracking zones, but never obtained a fix on him because he never entered our tracking zones. Therefore, entirely new tracking zones would have to be established in the eastern area if we are to track birds there. Prominent buttes are infrequent in the east and we would have

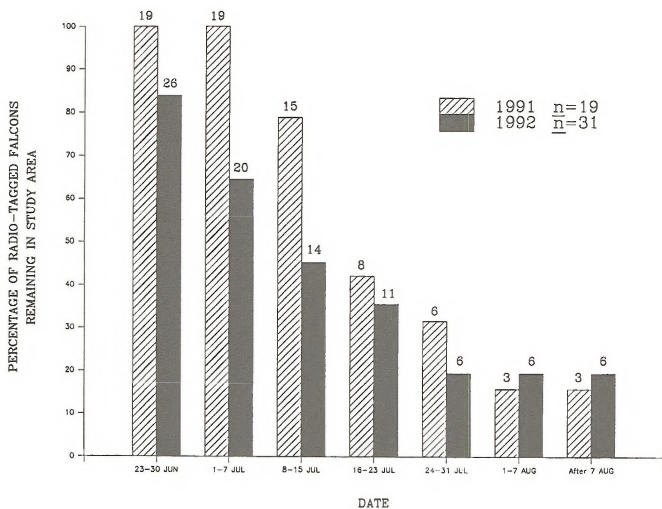


Fig. 17. Dispersal of radio-tagged prairie falcons from the study area in 1991 and 1992. We censused falcons from aircraft and from prominent receiver sites and recorded their presence or absence from the study area during the time intervals listed.

to use many tower sites. Aerial tracking was impractical in most of the eastern area because of the proximity of Mountain Home Air Force Base. We tracked the male from Rattlesnake Canyon once from a fixed-wing aircraft and located him inside the air base. Intensive military jet traffic encountered on this flight dissuaded us from future flights in the area!

Behavior of Nesting Prairie Falcons

Attendance in the territory and at the nest.--As in 1991, female falcons spent more of their time in their territories and close to their nests than did male falcons. When nestlings were less than 21 days old, females were observed in their territory an average of 73.7% of the time ($n = 15$, $SD = 16.5$), but males were observed in their territory only 43.5% of the time ($n = 15$, $SD = 17.1$). Females were in their territories an average of 59.6% ($n = 15$, $SD = 14.9$) of the time when nestlings were 21-40 days old, whereas males were in attendance 38.9% of the time ($n = 15$, $SD = 14.1$). When nestlings were less than 21 days old females were seen within 5 m of the aerie 42.2% of the time ($n = 15$, $SD = 24.5$), and males were seen near the nest 9.6% of the time when nestlings were less than 21 days old ($n = 15$, $SD = 7.3$). Both sexes reduced the time they spent at the nest as nestlings aged, but females still spent more of their time at the nest than did males (nestlings 21-40 days old: \bar{x} percentage of time female at nest = 4.3%, $n = 15$, $SD = 1.8$; \bar{x} for male = 2.2%, $n = 15$, $SD = 2.1$).

Parental attendance in the territory, based on visual observations, was influenced less by proximity of the aerie to the OTA in 1992 than in 1991. In 1992, most parents that nested within the OTA shadow spent less

time in their territories than parents that nested west of the OTA (Fig. 18a), but the trend was not significant in a repeated measures ANOVA controlling for brood size and hatch date (effect of OTA: $F_{1,10} = 0.63$, $P = 0.45$, there were no significant covariates or interactions). However, in 1991 and 1992, the influence of proximity to the OTA on parental attendance became accentuated as nestlings aged. The combined sample of parental attendance from 1991 and 1992 supported this trend; parents west of the OTA spent more time in their territory than parents in the OTA shadow, especially while tending nestlings > 21 days old (2-way interaction between proximity to the OTA and nestling age: $F_{1,21} = 4.1$, $P = 0.055$).

Assessment of parental attendance using radio telemetry in the observation blind confirmed our direct observations. The fairly insensitive nature of the omnidirectional antennas resulted in a loss of signal reception when the radio-tagged adults were on the benchland above the canyon nesting area. Males nesting west of the OTA shadow spent more time in radio contact while tending nestlings 21-40 days old than males nesting in the shadow ($\bar{x}_{OTA} = 61.4\%$, $n = 4$, $SD = 11.5$, $\bar{x}_{west} = 66.1\%$, $n = 4$, $SD = 12.3$). Males nesting in the shadow initially spent more time in radio contact while tending young nestlings than males nesting west of the shadow, but radio contact rates in the shadow dropped during brood rearing while rates west of the shadow increased. Therefore, the interaction between nestling age and proximity to the OTA on male radio contact time mirrored that found by visually monitoring territory attendance ($F_{1,4} = 6.6$, $P = 0.06$). Samples were insufficient to analyze females.

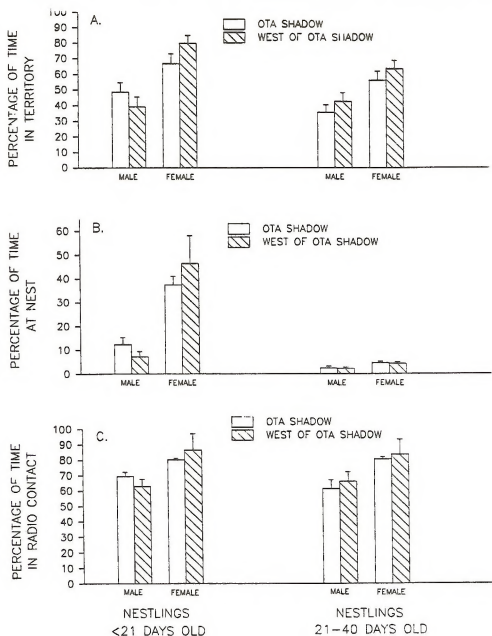


Fig. 18. Comparison of territory (A) and nest (B) attendance of prairie falcons nesting in the OTA shadow vs. nesting west of the OTA shadow, 1992. Percentage of time the radio-tagged member of the pair was in contact using an omnidirectional antenna on the observation blind (C) is also plotted. Average behaviors (± 1 SE) are presented separately for parents tending nestlings < 21 days old and those tending 21-40 day-old nestlings.

Parents nesting in the OTA shadow did not spend consistently more or less time in their territories on firing days. These differences were not significant, but sample sizes were small (Table 4).

Time spent near the nest was not related to a nest's proximity to the OTA. In 1992, as in 1991, falcons nesting in the OTA shadow spent about the same amount of time near their nest as parents nesting west of the OTA (Fig. 18b; $F_{1,10} = 0.22$, $P = 0.65$; no significant covariates or interactions). Combining 1991 and 1992 yielded the same result ($F_{1,22} = 0.29$, $P = 0.60$; no significant covariates or interactions). Parents in the OTA shadow tended to be near their nest a slightly greater percentage of the time on training days than on non-training days (Table 4).

Parental attendance generally was weakly correlated with hatch date. Males with nestlings less than 21 days old tended to spend more time in the territory as brood size and hatch date increased (Table 5). The positive correlation with hatch date was opposite to our 1991 findings, and is suspect because the correlation between attendance when nestlings were 21-40 days old and hatch date was negative. Neither variable was a significant covariate in the 1992 repeated measures ANOVAs testing for effects of nestling age, sex of parent, and proximity to the OTA. Hatch date continued to be an important covariate in the ANOVA for 1991 and 1992 combined ($F_{1,21} = 7.4$, $P = 0.01$), supporting the contention that parents of late hatching nests were less attentive than those at nests hatching early in the year.

Parental attendance was more closely related to brood size in 1992 than in 1991. Parents

tending large broods of 21-40-day-old nestlings spent more time at the nest than parents tending small broods (Table 5). The tendency for parental attendance at the nest to increase with increasing brood size, and for this relationship to be stronger as nestlings aged, was also evident in 1991.

Parents tended to spend less time in the territory and significantly less time at their nests as nestlings aged (Table 6). Correlation analyses for the 1992 data using each day of observation as an independent sample of behavior did not support the 1991 finding that differences in these relationships were contingent upon proximity of the territory to the OTA (Table 6). Parents showed strong reductions in attendance as nestlings aged regardless of whether they nested in the OTA shadow or west of the shadow.

Delivery of prey items.--Males tended to deliver more prey items to nestlings than females (Fig. 19b; $F_{1,10} = 3.8$, $P = 0.08$), and proximity to the OTA interacted with age of nestlings to influence the total number of items delivered ($F_{1,10} = 7.1$, $P = 0.02$). The interaction was significant because parents in the OTA shadow sharply increased their prey delivery rates as nestlings aged, but parents west of the shadow maintained high rates throughout the nesting cycle (Fig. 19b). This trend was not seen in 1991 and was not significant when both years of data were combined ($F_{1,24} = 0.95$, $P = 0.34$).

In 1992, we recorded all items brought into the territory as well as those delivered to the nestlings. An interaction between sex of the parent and proximity to the OTA approached significance ($F_{1,10} = 3.8$, $P = 0.08$) in the analysis of prey deliveries to the territory. Females tended to deliver few items to the

Table 4. Average parental behavior at nests in the OTA shadow on firing and non-firing days, 1991 and 1992. Observations were made within 1-5 days of each other at each nest once on firing and once on non-firing days. F-statistics are from 1-way ANOVAs comparing means. Samples of caching rates were insufficient for analysis.

Parental Behavior	Ranges Firing			Ranges Not Firing			F	DF	P
	\bar{x}	\underline{n}	SD	\bar{x}	\underline{n}	SD			
<u>Time (%) in Territory</u>									
Male	24.5	12	19.2	27.3	9	13.7	0.60	1,8	0.46
Female	40.7	12	26.3	33.6	9	24.8	2.58	1,8	0.15
<u>Time (%) at Nest</u>									
Male	8.1	12	13.9	6.9	10	13.2	1.03	1,10	0.33
Female	21.5	12	24.8	9.4	10	14.1	2.65	1,10	0.14
<u>Prey Deliveries to Nest/Hr</u>									
Male	0.23	13	0.11	0.25	13	0.11	0.27	1,12	0.61
Female	0.19	13	0.15	0.17	13	0.10	0.05	1,12	0.83
Total	0.41	13	0.14	0.42	13	0.13	0.04	1,12	0.85
<u>Caches/Hr</u>									
Male	0.00	4	0.00	0.02	4	0.03			
Female	0.03	4	0.06	0.03	4	0.04			
Total	0.03	4	0.06	0.05	4	0.03			

Table 5. Pearson correlations between hatching date, brood size, and parental behavior at all nests in 1992. Percentages were transformed prior to analysis (arcsine of square root).

Parental Behavior	HATCHING DATE			BROOD SIZE		
	<i>r</i>	<i>n</i>	<i>P</i>	<i>r</i>	<i>n</i>	<i>P</i>
<u>Percentage of Time in Territory</u>						
male (nestlings <21 days old)	0.45	(21)	0.04	0.39	(21)	0.08
(nestlings 21-40 days old)	-0.26	(26)	0.20	0.00	(26)	1.00
female (nestlings <21 days old)	-0.28	(21)	0.22	0.06	(21)	0.81
(nestlings 21-40 days old)	-0.11	(26)	0.61	0.04	(26)	0.83
<u>Percentage of Time at Nest</u>						
male (nestlings <21 days old)	0.24	(21)	0.30	-0.12	(21)	0.60
(nestlings 21-40 days old)	-0.27	(26)	0.19	0.39	(26)	0.05
female (nestling <21 days old)	-0.07	(21)	0.78	-0.21	(21)	0.37
(nestlings 21-40 days old)	-0.21	(26)	0.32	0.33	(26)	0.10
<u>Prey Deliveries to Nest per Hr</u>						
male (nestlings <21 days old)	-0.01	(22)	0.97	-0.25	(22)	0.26
(nestlings 21-40 days old)	-0.02	(26)	0.93	0.49	(26)	0.01
female (nestlings <21 days old)	-0.42	(22)	0.05	-0.14	(22)	0.01
(nestlings 21-40 days old)	-0.37	(26)	0.07	0.12	(26)	0.56
total (nestlings <21 days old)	-0.23	(22)	0.30	-0.25	(22)	0.27
(nestlings 21-40 days old)	-0.33	(26)	0.11	0.49	(26)	0.01
<u>Prey Deliveries to Territory per Hr</u>						
male (nestlings <21 days old)	-0.26	(22)	0.25	-0.20	(22)	0.37
(nestlings 21-40 days old)	-0.17	(26)	0.41	0.43	(26)	0.03
female (nestlings <21 days old)	-0.09	(22)	0.69	-0.09	(22)	0.71
(nestlings 21-40 days old)	-0.40	(26)	0.05	0.19	(26)	0.36
total (nestlings <21 days old)	-0.30	(22)	0.18	-0.24	(22)	0.29
(nestlings 21-40 days old)	-0.41	(26)	0.04	0.49	(26)	0.01
<u>Caches per Hr</u>						
male (nestlings <21 days old)	-0.24	(22)	0.29	0.17	(22)	0.44
(nestlings 21-40 days old)	0.01	(26)	0.98	0.18	(26)	0.38
female (nestlings <21 days old)	-0.31	(22)	0.16	-0.36	(22)	0.10
(nestlings 21-40 days old)	-0.11	(26)	0.67	-0.09	(26)	0.25

Table 6. Pearson correlations between age of nestlings (days) and parental behavior at nests inside the OTA Shadow and west of the OTA Shadow in 1992. Percentages were transformed prior to analysis (arcsine of square root).

Parental Behavior	OTA nests			West of OTA nests		
	<u>r</u>	<u>n</u>	<u>P</u>	<u>r</u>	<u>n</u>	<u>P</u>
<u>Time (%) in territory</u>						
Male	-0.32	(30)	0.08	-0.31	(21)	0.18
Female	-0.45	(30)	0.01	-0.37	(21)	0.10
<u>Time (%) at nest</u>						
Male	-0.74	(31)	<0.001	-0.75	(21)	<0.001
Female	-0.87	(31)	<0.001	-0.84	(21)	<0.001
<u>Prey deliveries to nest per hr</u>						
Male	0.51	(32)	0.003	0.30	(21)	0.19
Female	0.44	(32)	0.01	0.16	(21)	0.49
Total	0.67	(32)	<0.001	0.29	(21)	0.21
<u>Prey deliveries to territory per hr</u>						
Male	0.39	(32)	0.03	0.26	(21)	0.26
Female	0.35	(32)	0.05	0.29	(21)	0.21
Total	0.54	(32)	0.001	0.37	(21)	0.10
<u>Caches per hr</u>						
Male	-0.30	(32)	0.09	-0.09	(21)	0.71
Female	-0.24	(32)	0.19	-0.08	(21)	0.75
Total	-0.32	(32)	0.07	-0.11	(21)	0.62

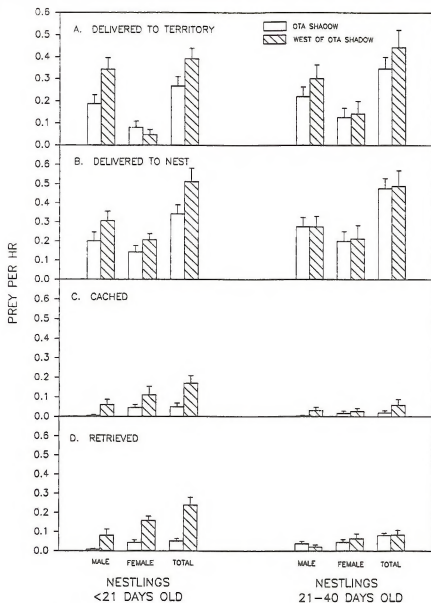


Fig. 19. Comparison of food handling behaviors by prairie falcons nesting in the OTA shadow vs. west of the OTA shadow, 1992. Delivery of fresh items into the territory (A), delivery of all items to the nestlings (B), caching (C) and retrieval (D) of all items are plotted as rates per hour of observation. Average behaviors (+ 1 SE) are presented separately for parents tending nestlings <21 days old and those tending 21-40 day old nestlings. Delivery of items into the territory are minimum rates because items not able to be classified as fresh or old are not included. Likewise, retrievals do not include items not known to be previously cached and are therefore minimum rates.

territory regardless of proximity to the OTA, but males in the OTA shadow tended to bring fewer items to the territory than males west of the shadow (Fig. 19a). Age of nestlings and brood size also interacted significantly ($F_{1,10} = 10.0, P = 0.01$) because deliveries increased rapidly with increases in brood size when nestlings were 21-40 days old ($r = 0.63, n = 14, P = 0.02$), but not when they were < 21 days old ($r = -0.13, n = 14, P = 0.66$).

Caching and retrieval were recorded in sufficient detail in 1992 to allow analyses of these processes. Caching tended to be most frequent when nestlings were < 21 days old ($F_{1,10} = 1.7, P = 0.22$) and done more by females than males ($F_{1,10} = 2.5, P = 0.15$). The most interesting effect, however, was the tendency for caching to be more common at sites west of the OTA than at sites in the OTA shadow (Fig. 19c; $F_{1,10} = 4.1, P = 0.07$). Cache retrieval was also seen more at nests west of the OTA than at nests in the OTA shadow ($F_{1,10} = 7.1, P = 0.02$). The OTA effect, however, depended upon the age of nestlings; parents west of the OTA reduced cache retrieval sharply as their nestlings aged, but those in the OTA shadow retrieved caches at low, but equal, rates regardless of nestling age (Fig. 19d; $F_{1,10} = 7.8, P = 0.02$).

Subtracting the number of retrievals from caches from the number of deliveries to caches gives an indication of the flux of stored food in a territory on a given day. On average, retrievals were more common than deliveries to caches so territories had slightly negative balances. This probably reflects the tendency for many items to be stored 1 day, but retrieved on the following day (Holthuijzen 1990). The size of the balance was significantly affected by

nestling age and proximity of the nest to the OTA (2-way interaction, $F_{1,10} = 10.6, P = 0.01$). Balances at sites in the OTA shadow became more negative as nestlings aged (\bar{x} total caches - total retrievals: nestlings < 21 days old = -1.3, $n = 7, SD = 0.49$; nestlings 21-40 days old = -3.6, $n = 8, SD = 2.4$), but balances at sites west of the OTA improved as nestlings aged (\bar{x} total caches - total retrievals: nestlings < 21 days old = -1.75, $n = 8, SD = 2.9$; nestlings 21-40 days old = -1.0, $n = 8, SD = 1.4$).

Prey delivery rates at nests in the OTA shadow were not significantly different when training occurred versus days when training did not occur on ranges (Table 4). Delivery of items to the territory were not analyzed because of small sample size (they were only recorded in 1992).

Delivery rate of prey to nestlings by parents was correlated with brood size to a lesser extent in 1992 (Table 5) than in 1991. The few significant correlations in 1992 were positive (as in 1991) indicating that parents delivered more food items to large broods than small ones. Deliveries to the territory were also weakly correlated with brood size and tended to increase with increasing brood size (Table 5).

Hatch date also was correlated with the prey delivery rates to a lesser extent in 1992 (Table 5) than in 1991. The few significant correlations in 1992 indicated that, as in 1991, parents reduced their delivery rates at nests that hatched late in the season. Deliveries to the territory also showed this trend (Table 5).

Caching rate was not significantly correlated with either brood size or hatch date (Table 5). Caching tended to be lowest on firing

days, but our sample of paired observations was small (Table 4).

Townsend's ground squirrels were the most common food item delivered to nestlings in 1992. Sixty-three percent of 136 prey items brought to nests west of the OTA were Townsend's ground squirrels as were 56% of 196 items delivered to nestlings within the OTA shadow (Fig. 20). Falcons nesting within the OTA shadow delivered fewer Townsend's ground squirrels and more kangaroo rats, birds, and reptiles to their nestlings than falcons nesting west of the OTA. In fact, we did not observe birds west of the OTA deliver kangaroo rats, birds, or reptiles to their nestlings in 1992. The distribution of prey items brought to nests in the OTA shadow differed significantly from the distribution of items brought to nests west of the OTA (Likelihood ratio test on categories in Fig. 20 lumping kangaroo rats, birds, and reptiles: $G^2_{(3)} = 9.3$, $P = 0.03$). A similar trend was observed in 1991, and combining results from both years yields a highly significant difference between the diets of birds nesting in the OTA shadow and those nesting west of the shadow (Likelihood ratio test as above: $G^2_{(3)} = 11.1$, $P = 0.01$).

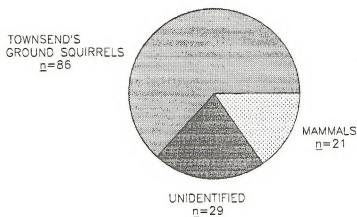
Diets were less variable in 1992 relative to 1991. Townsend's ground squirrels comprised a larger fraction of the falcons' diets regardless of where they nested in 1992 compared to 1991. Only 6 non-mammal items were identified in 1992, and insects were not delivered to any nest during our observations.

The diurnal pattern of delivery rates described in 1991 was evident in 1992. Few deliveries were made early in the morning or late in the evening. Instead, rates peaked in

mid-morning and again in late afternoon, with a midday lull (Fig. 21b,f). The distribution of deliveries throughout the day did not differ between OTA sites and sites west of the OTA (Likelihood ratio test on categories in Fig. 21 lumping 0 - 1 hr after sunrise and 14 - 16 hr after sunrise: $G^2_{(13)} = 15.0$, $P = 0.31$). Delivery rates to the nesting area also showed a bimodal distribution with peaks in mid-morning and late afternoon (Fig. 21a,e). Delivery rates to the territory began later in the day than deliveries to the nest, especially west of the OTA shadow, because early deliveries to the nest were retrieved from caches. Cache and retrieval rates showed a tendency to be bimodally distributed throughout the day, but their rarity made detection of a pattern difficult (Fig. 21c,d,g,h).

Influence of behavior on production of fledglings.--In 1991, parental attendance in the territory was positively correlated with fledgling success. In 1992, however, this was not the case. Parental attendance in the territory and at the nest was very weakly correlated with the number of fledglings produced (male attendance in territory: $r = -0.56$, $n = 10$, $P = 0.09$; female attendance: $r = -0.41$, $n = 10$, $P = 0.23$). Combining 1991 and 1992 yielded no significant correlations between the number of fledglings and parental attendance (male attendance: $r = -0.06$, $n = 20$, $P = 0.80$; female attendance: $r = -0.03$, $n = 20$, $P = 0.90$). Attendance within 5 m of the nest was not related to the production of fledglings in 1992 (male attendance: $r = 0.03$, $n = 10$, $P = 0.94$; female attendance: $r = 0.07$, $n = 10$, $P = 0.84$), but tended to increase with increasing fledgling success when data from 1991 and 1992 were pooled (male attendance: $r = 0.41$, $n = 21$, $P = 0.06$;

A) WEST OF OTA SHADOW



B) OTA SHADOW

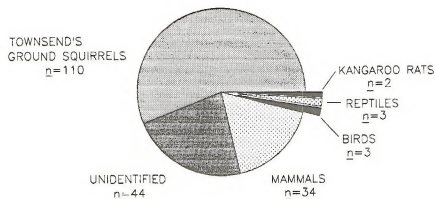


Fig. 20. Composition of prey items delivered to nestling prairie falcons in the OTA shadow compared to west of the OTA shadow, 1992. Percentages are plotted as pieces of a pie totaling 100%. Actual numbers of each prey type are listed as n .

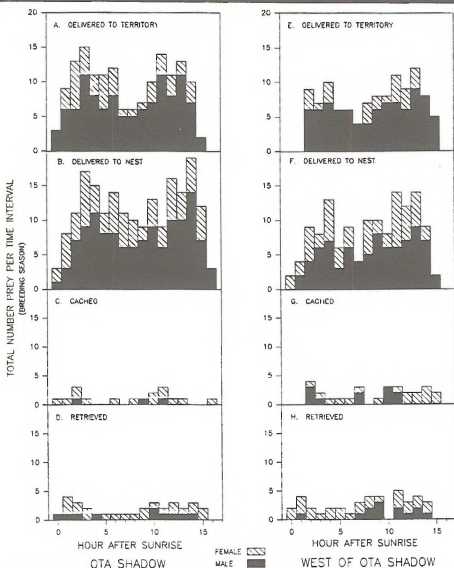


Fig. 21. Timing of the total number of prey items delivered to the territory and the nest, cached, and retrieved by adult prairie falcons during the 1992 breeding season. Delivery rates to the territory and retrieval rates from caches are minimum as explained in Fig. 19. The total number of items is plotted which is sensitive to observation time and is not comparable between OTA shadow sites and west of OTA shadow sites. Relative differences throughout the day are comparable because each hour was observed the same number of times. Total prey items handled by falcons for each portion of this figure are as follows: A) male $n = 110$, female $n = 43$, B) male $n = 125$, female $n = 70$, C) male $n = 14$, D) male $n = 10$, female $n = 22$, E) male $n = 87$, female $n = 23$, F) male $n = 82$, female $n = 52$, G) male $n = 11$, female $n = 17$, H) male $n = 13$, female $n = 27$.

female attendance: $r = 0.44$, $n = 21$, $P = 0.05$).

Military Training and Raptor Abundance

Paired observations at ranges.—Our experiment using 8 tank and artillery ranges revealed that raptors were less abundant on training than non-training days. However, as we reported for 1991, this response was not uniform throughout the season or throughout the day. The mean abundance of raptors was always highest when training was not occurring. However, the difference in abundance on training and non-training days was significant only during mid-season (Fig. 22b), and this effect was contingent upon the time of day (interaction between firing activity and time of day: multivariate $F_{3,4} = 8.4$, $P = 0.03$). Differences in abundance on days with and without training were not significant during the early season (Fig. 22a; $F_{1,5} = 0.30$, $P = 0.54$) and late season (Fig. 22c; $F_{1,5} = 0.66$, $P = 0.45$). There were no significant interactions between activity on the ranges and time of day during the early and late season, but raptors tended to be less abundant as the day progressed late in the season, regardless of military activity (Fig. 22c; $F_{3,3} = 6.8$, $P = 0.08$).

The influence of temperature and wind speed on raptor abundance was not directly taken into account in the repeated measures analyses presented above. However, analyses of average temperature and wind speed throughout the day on training and non-training days suggested that these factors did not influence our results. Temperatures increased throughout the day in all seasons (Fig. 23), but the patterns of increase were similar on training and non-training days during the early season ($F_{1,5} =$

1.3 , $P = 0.31$) and late season ($F_{1,5} = 0.35$, $P = 0.58$). Wind speed varied less throughout the day during the early and late season, and did not differ significantly on training and non-training days (Fig. 23; early season: $F_{(1,7)} = 3.2$, $P = 0.12$; late season: $F_{(1,8)} = 2.3$, $P = 0.17$). During mid-season, temperature and wind speed changes on training and non-training days differed (interaction between time of day and military activity on temperature: multivariate $F_{3,4} = 20.0$, $P = 0.01$; on wind speed: multivariate $F_{(3,7)} = 6.2$, $P = 0.02$). These interactions are unlikely to account for the interaction between training and time of day reported for raptor abundance because differences throughout the day in the weather factors on training and non-training days became more disparate while differences in raptor abundances became less disparate (compare Fig. 22b with Fig. 23b,e).

Plots of raptor abundances against temperature and wind speed simultaneously in 3 dimensions illustrate the differences between firing and non-firing days under various weather regimes (Fig. 24a,b). Regardless of firing activity, raptors were most abundant when winds and temperatures were low to moderate, but peak abundances during these conditions were higher on non-training days. Non-training ranges also had higher raptor abundances than training ranges when winds increased beyond 25 km/hr.

Combining observations from 1991 and 1992 strengthened the observation that raptors were observed less frequently on training days than on non-training days, and that the difference depended upon the season. During mid-season, raptors were consistently observed less frequently on training days relative to non-training days ($F_{1,12} = 6.7$, $P =$

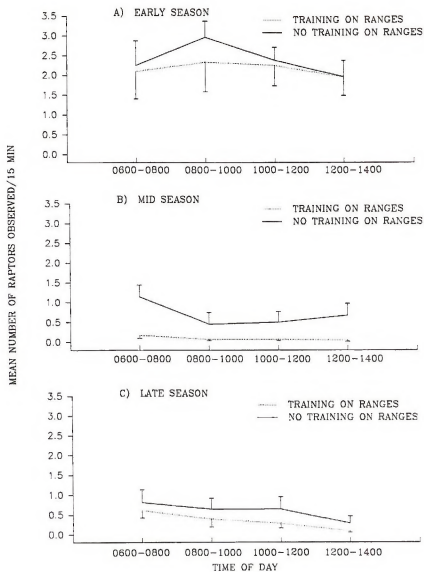


Fig. 22. Number of raptors observed on military tank firing and artillery ranges throughout the day in each of 3 seasons, 1992. Average \pm 1 SE are plotted for ranges during training versus no training. Early season includes the first pair of observations made on each range and spans the period from 3 March - 13 May. Mid-season includes the second pair of observations made on each range and spans the period from 27 May - 26 June. Late season includes the third pair of observations made on each range and spans the period from 7 July - 27 July.

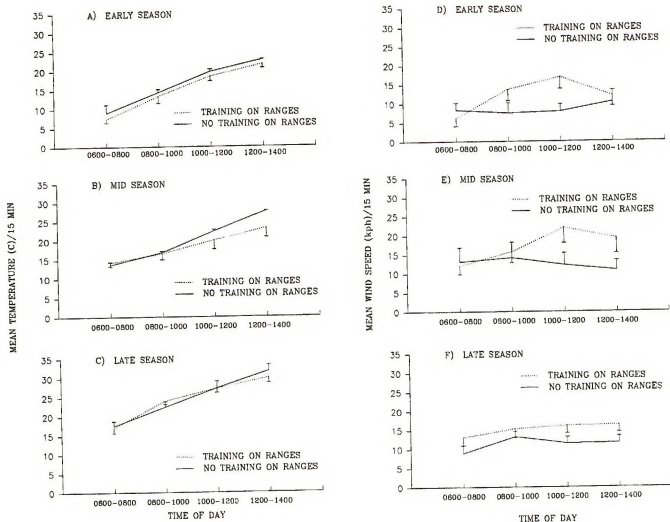
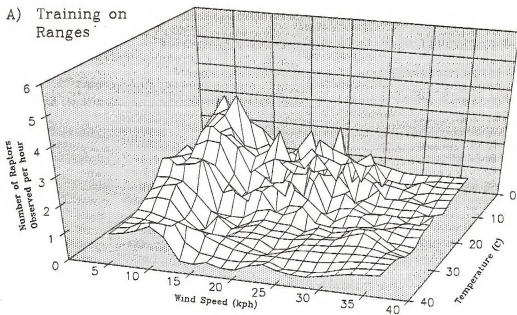


Fig. 23. Temperature and wind speed during observations on tank an artillery ranges. Weather was recorded during the observations on raptors plotted in Fig. 22. See Fig. 22 for definition of seasonal intervals.

A) Training on
Ranges



B) No Training on
Ranges

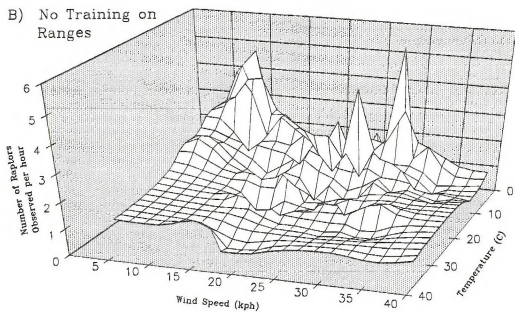


Fig. 24. Numbers of raptors counted on tank and artillery ranges in relation to temperature and wind speed. Counts were made during all observation sessions plotted in Fig. 22.

0.02). However, during the early season ($F_{1,11} = 0.21, P = 0.65$) and late season ($F_{1,11} = 0.43, P = 0.53$) raptor abundance did not differ significantly on training and non-training days. Time of day was not a significant interactive factor with military activity in any season, but there were significantly fewer birds as the day progressed during the mid-season (multivariate $F_{3,10} = 11.4, P = 0.001$), and a tendency for a similar decline during the late season (multivariate $F_{3,9} = 3.7, P = 0.06$).

Prairie falcon counts were influenced by military training in the same way as the total number of raptors. We combined our counts of prairie falcons on the ranges in 1991 and 1992. Prairie falcons were observed more frequently on non-training days than on training days (Fig. 25). The difference was significant during mid-season ($F_{1,9} = 8.2, P = 0.02$), but not significant during early ($F_{1,9} = 0.93, P = 0.36$) or late ($F_{1,9} = 0.45, P = 0.52$) seasons.

The influence of military training appeared to lessen late in the afternoon. We counted raptors on 1 range (Range 10) throughout the day on training and non-training days (Fig. 26). On these days, maximum differences between training and non-training days occurred in the morning, but more data are needed.

Observations at all ranges.--The effect of training also was evident in our sample of all observations at 13 ranges and 2 bivouac sites (Fig. 27). Artillery training and tank training that involved firing (the main turret guns and/or the machine guns) were associated with the lowest levels of raptor activity (Fig. 27a). Tank training that did not involve live ammunition (preparation, driving and/or laser training), firing of small

arms, and convoy traffic on the Range Road were associated with levels of raptor activity similar to activity when no training occurred. The differences in raptor activity were significant across all types of military activity ($F_{4,164} = 2.64, P = 0.04$), but not significant when we compared average activity on days with no training, "quiet" tank training, and Range Road traffic to activity on days with tank, mortar, or small arms firing ($F_{1,167} = 0.58, P = 0.45$). Temperature and wind speed were significant covariates in both analyses (temperature: all military activity: $F_{1,165} = 24.9, P < 0.001$; lumped activity: $F_{1,168} = 26.8, P < 0.001$; wind speed: all military activity: $F_{1,164} = 22.05, P < 0.001$; lumped activity: $F_{1,167} = 21.5, P < 0.001$).

The effect of the type of military training reported above was less in 1992 than in 1991, but trends were in the same direction both years and therefore the combined analysis of 1991-1992 was highly significant. Raptor abundance varied across all 6 categories of military activity ($F_{5,322} = 3.7, P = 0.003$) and between firing and non-firing activities ($F_{1,326} = 4.7, P = 0.031$). Temperature and wind speed were significant covariates in both analyses (temperature: all military activity: $F_{1,324} = 65.1, P < 0.001$; lumped activity: $F_{1,327} = 66.096, P < 0.001$).

We observed 2 bivouac sites in 1992, 1 during mid-season and 1 during late season. Few raptors used these areas during our observations, but there was a tendency for abundance to be greater on days when the military was inactive than on days with activity, especially late in the season (Fig. 28). Sample sizes are currently too small to analyze.

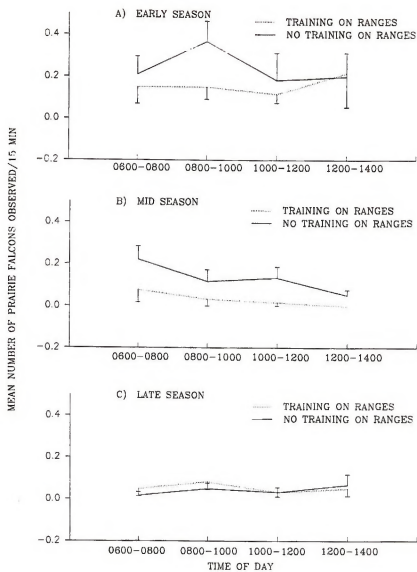


Fig. 25. Number of prairie falcons observed on military tank training and artillery ranges throughout the day in each of 3 seasons, 1992. Average \pm 1 SE are plotted on days when training occurred on the range versus days when no training occurred. Seasons are described in the legend on Fig. 22.

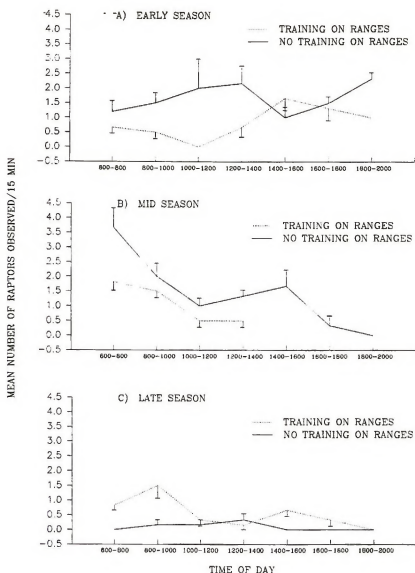


Fig. 26. Number of raptors observed during full-day observations at 1 tank training range during laser firing in each of 3 seasons, 1992. Average \pm 1 SE are plotted for days when training occurred on the range versus days when no training occurred. Early season observations were made on 6 May and 13 May. Mid season observations were made on 28 June and 25 June. Late season observations were made on 16 July and 24 July. Data were unavailable for the evening session during mid-season on the training day.

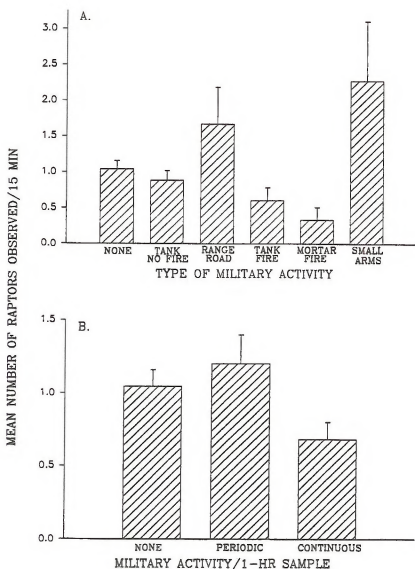


Fig. 27. Average number of raptors (+ 1 SE) observed on military training ranges under different firing regimes, 1992. Type of military activity on the range (A) was categorized as: none = no activity, Tank/no fire = driving, preparing, laser-training tanks, range road = convoy traffic on the range road, tank/fire = tanks shooting main turret gun and/or machine guns, mortar fire = artillery firing, and small arms = M-60, M-16, M-40 rifle and 45 pistol firing. Military activity per hr (B) was categorized as none = no activity, periodic = activity punctuated by periods of inactivity, and continuous = sustained activity during entire hr.

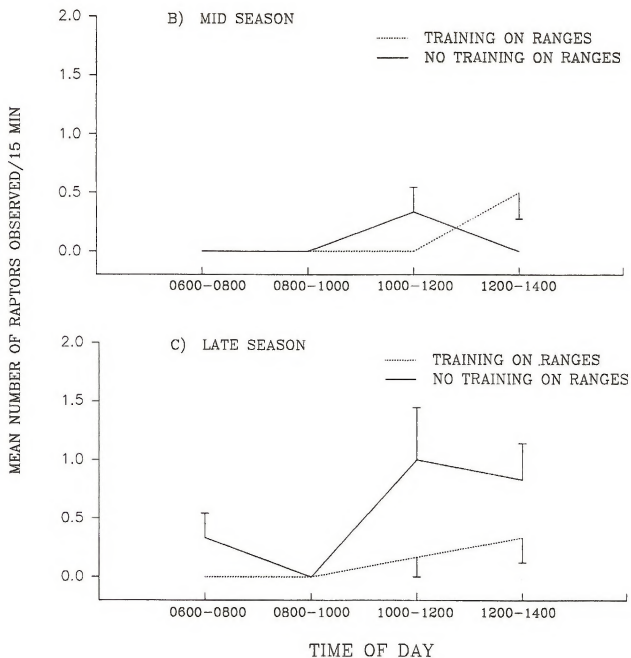


Fig. 28. Number of raptors observed at bivouac/maintenance sites throughout the day in each of 2 seasons, 1992. Average \pm 1 SE are plotted for training and non-training days. Mid-season observations occurred on 30 June and 10 July. Late season observations were made on 14 July and 24 July.

The consistency of military activity during our samples of raptor abundance influenced the number of raptors observed. Activity on ranges was not constant during each of our samples; the number of raptors counted was highest when there was periodic or no training on the range and lowest when there was continuous training during the 1-hr observation period (Fig. 27b; $F_{2,168} = 3.87$, $P = 0.023$). This was similar to our findings in 1991, and therefore combining data from 1991 and 1992 yielded a highly significant effect of training consistency on raptor abundance ($F_{2,330} = 9.49$, $P < 0.001$). Temperature and wind speed were significant covariates in both analyses (1992: $F_{1,166} = 29.6$, $P < 0.001$; 1991-1992: $F_{1,330} = 50.8$, $P < 0.001$). Wind speed was a significant covariate in 1992 ($F_{1,166} = 16.6$, $P < 0.001$).

Military training and raptor behavior.--In 1992, as in 1991, the 4 major groups of raptors using the training ranges exhibited species-typical repertoires of behavior. Northern harriers spent most of their time in flapping and gliding flight low to the ground and often perched (Fig. 29a). Short-eared owls (*Asio flammeus*) and burrowing owls (*Speotyto cunicularia*) were rarely seen in 1992, but continued to deviate rarely from perching and flying low to the ground (Fig. 29b). Buteos soared more than any other group and often perched and flew low across the ranges (Fig. 29c). Rough-legged hawks (*Buteo lagopus*) were especially common members of the buteo group in 1992, particularly early in the season. Falcons commonly used low flapping flight to traverse the area, but also often glided, soared, and perched (Fig. 29d).

Visual inspection of Fig. 29 reveals similarities and differences in the way each

species group behaved on training and non-training days (compare C and H bars), and how each group utilized the area in versus out of the firing fan (compare shading in bars). All groups tended to be most active on days without firing ("C" bars); however, harriers and owls exemplified this pattern, and buteos showed the least difference in behavior on training versus non-training days. All groups also exhibited most behaviors out of the firing fan (open portion of bars). Falcons exhibited a greater percentage of behaviors inside the fan than other groups, and attacked more often inside fans than outside them.

The most stringent test of the hypothesis that behavior was not influenced by military training is to compare behavior in versus out of the firing fan on training versus non-training days. This was tested by the 3-way interaction between behavior, location in or out of the fan, and activity on the range in our log-linear models of 9 behavioral categories (see methods for description of categories). Using only the 1992 data, the null hypothesis that the activity on the range did not influence the repertoire of behavior in the firing fan could be rejected only for falcons (Fig. 30; tests of the 3-way interaction for falcons: $G^2_{(8)} = 22.2$, $P = 0.005$; buteos: $G^2_{(8)} = 11.4$, $P = 0.18$; northern harriers: $G^2_{(8)} = 7.95$, $P = 0.44$; owls: sample size too small to analyze).

The significant 3-way interaction for falcons reflected their varied behavioral repertoires which depended upon the activity on the ranges. They perched and traveled at low heights (PE, TF1, TF2) relatively equally in versus out of the fan and more on non-training than training days, but they traveled at the highest heights (TF3) most frequently on training days, and spent most of their

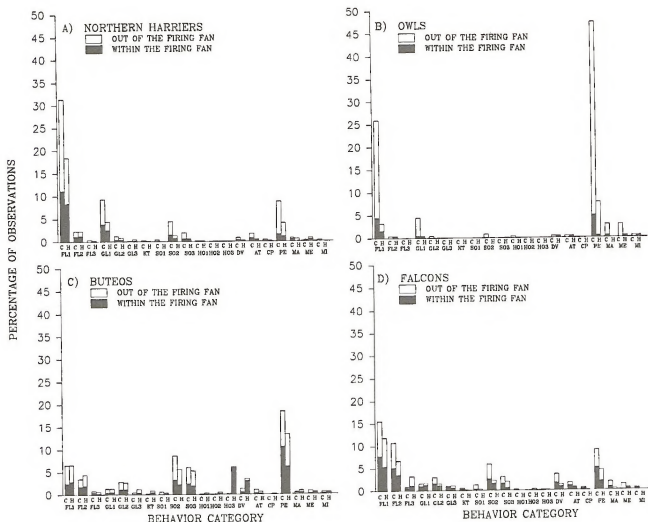


Fig. 29. Full repertoire of behaviors recorded for 4 groups of raptors utilizing the military firing ranges, 1992. Percentage use of each behavior is compared on non-firing days (C) and firing days (H). Within each bar we show the percentage of each behavior recorded inside the firing fan relative to outside of the firing fan. Behavior codes are either a behavior or a combination of a behavior and a height code (1 = 0-10m , 2 = 10-30m, 3 = over 30m) and are abbreviated as follows: FL- flapping flight, GL- gliding flight, SO- soar, DV- dive, HO- hover, PE- perch, AT-attack, PR- preen, MA- intraspecific maneuver, ME- interspecific maneuver, MI- individual maneuver, KT- kiting, AT- attack, CP- carry prey.

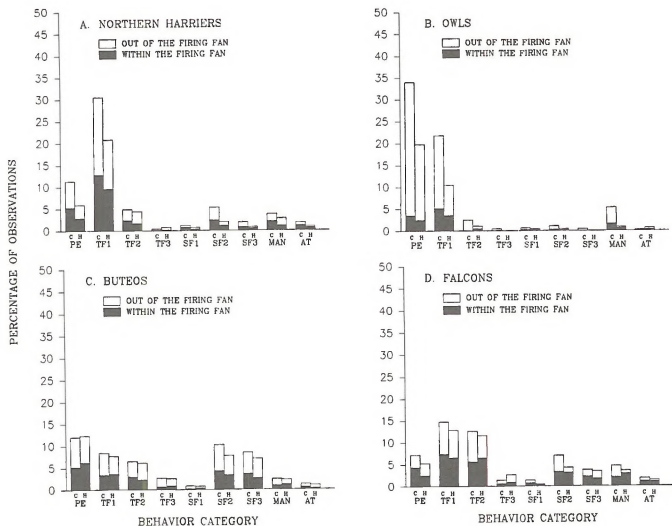


Fig. 30. Condensed repertoire of behaviors recorded for 4 groups of raptors utilizing the military training ranges, 1992. See legend in Fig. 29 for detail.

time soaring, maneuvering, and attacking (SF2, SF3, MAN, AT) on training days inside the fan (Fig. 30d).

Buteos and harriers showed less variation in behaviors with respect to activity on the ranges. Both groups tended to perform most behaviors more on days without training than days with training (Fig. 30a,c). However, they showed considerable variation in the proportion of each behavior exhibited in versus out of the fan. Harriers rarely did anything inside the fan except fly low to the ground (Fig. 30a, TF1). Buteos perched more often in the fans than outside them, traveled low in the fans and outside of them with relatively equal frequency, and soared, maneuvered, and attacked most often outside the fans (Fig. 30c). Differences in behavior in versus out of the fan are quantified by the 2-way interaction between location and behavior in the log-linear model. These interactions are the only significant effects for buteos ($G^2_{(8)} = 48.0, P < 0.001$) and harriers ($G^2_{(8)} = 22.6, P = 0.005$).

Combining data from 1991 and 1992 increased our sample size of rare behaviors and led to some changes in our perception of how raptors use the training ranges (Fig. 31). Falcons continued to exhibit variation in behavior depending upon training activity and location in versus out of the firing fan (3-way interaction: $G^2_{(8)} = 21.9, P = 0.005$). The same pattern described above for 1992 is evident in the 1991-92 sample (Fig. 31d).

Buteos exhibited small differences in behaviors on training versus non-training days, but showed significant variation in the degree to which a behavior is performed in versus out of the firing fan (Fig. 31c; 2-way interaction between location and behavior: $G^2_{(8)} = 24.5, P < 0.01$). The 3-way

interaction for buteos approached significance ($G^2_{(8)} = 14.2, P = 0.08$). Buteos perched relatively equally in and out of the fan, but flew low to the ground (TF1, TF2) and soared high (SF2, SF3) slightly more out of the fan, and traveled high (TF3), soared low (SF1), and attacked (AT) primarily outside the fan.

Harriers exhibited similar behavioral repertoires inside and outside of the firing fan, but varied behavior significantly on training versus non-training days (2-way interaction between military activity and behavior: $G^2_{(8)} = 22.8, P < 0.01$). They perched, flew low to the ground (TF1), soared (SF2, SF3), and attacked (AT) much more frequently on non-training days than training days. However, they traveled at moderate heights (TF2), soared low (SF1), and maneuvered (MAN) nearly equally on training and non-training days, and traveled high (TF3) most frequently on training days (Fig. 31a).

Owls exhibited a very limited behavioral repertoire, even when we combined 1991-92 (Fig. 31b). As a result, the many changes in use of rare behaviors with respect to location and military activity yielded a significant 3-way interaction ($G^2_{(2)} = 9.0, P = 0.01$). This result may be misleading until it can be confirmed with a larger sample size of rare behaviors because the 3 most common behaviors (PE, TF1, and MAN) all showed a consistent pattern of greater occurrence outside the fan and on non-training days.

The occurrence and fate of prey capture attempts did not depend upon military training activities. In 1992, we observed 86 attempts to capture prey by raptors on training ranges; 20 (23.3%) were successful,

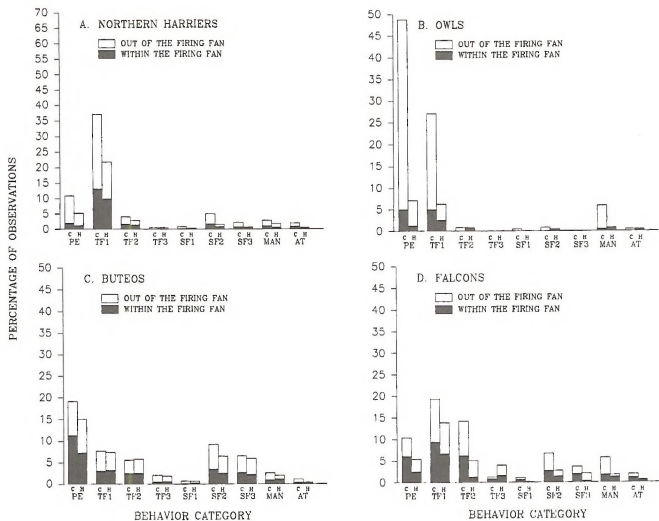


Fig. 31. Condensed repertoire of behaviors recorded for 4 groups of raptors utilizing the military firing ranges in 1991 and 1992. See legend in Fig. 29 for detail.

48 (55.8%) were unsuccessful, and the fates of 18 (20.9%) were not determined. Attempts occurred on training versus non-training days and in versus out of the firing fan with similar frequency in 1992 ($\chi^2_{(1)} = 0.5, P = 0.48$), and in the combined sample of 198 attacks from 1991-1992 ($\chi^2_{(1)} = 0.003, P = 0.96$). Furthermore, success rate did not differ with respect to military training or location of the attempt relative to the firing fan (3-way contingency table comparing success versus failure, in relative to out of the fan, on training versus non-training days: 1992 data: $\chi^2 = 1.7, P = 0.20$; 1991-1992 data: $\chi^2 = 1.5, P = 0.22$).

The average attack rate per hr on ranges tended to be lower on training days than on non-training days. Total attacks per hr averaged 0.11 ($n = 15, SD = .11$) on non-training days, but only 0.07 ($n = 15, SD = 0.06$) on training days ($F_{(1,14)} = 3.8, P = 0.07$). The rate of attempts inside versus outside the firing fans did not differ on training versus non-training days (2-way interaction between location and training: multivariate $F_{(3,12)} = 0.70, P = 0.57$).

Golden Eagles

Trapping.--We trapped a total of 11 eagles in 27 trapping days (see Appendix B for physical characteristics); 7 of these eagles were target breeding adults or subadults, and 4 were non-target eagles (2 hatch-year birds and 2 subadults). One of the non-target subadults was associated with the breeding female at the Beercase territory, but did not breed and was apparently displaced from the territory by an adult male that we subsequently captured and instrumented. The other non-target subadult was also captured in the Beercase territory. Hatch-

year birds were captured at the PP&L 119 and Black Butte territories.

All successful trap attempts were preceded by the presence of corvids (either magpies [*Pica pica*] or ravens [*Corvus corax*]) at the sets. Although we tried to minimize capture of non-target species, 7 ravens and 2 magpies were caught (Appendix C). These birds were usually caught after being at sets for an extended period of time, which probably caused the trap pans to be slowly depressed to a point at which the traps could be easily triggered. The broadcast of static over a 2-way radio buried nearby helped to keep ravens away from the carcass, but did not frighten them out of the area. Magpies were generally less affected by the noise and, while sometimes flushing from the carcass, would usually quickly return to feeding. Coyotes were successfully deterred from disturbing the sets by the use of radios, although we often had to yell repeatedly to keep them away from the carcasses. Before using radios, we had 2 instances of coyotes stealing carcasses, even though we used scent marking to keep mammalian scavengers away.

All captured eagles initially approached sets from perches, and the majority (7 of 10, 1 unknown, see Appendix C for trapping summaries) were caught immediately upon landing at or walking up to sets. We had 7 cases of eagles feeding at sets and not being trapped. Delays or failures to capture eagles were usually associated with wet soil and abundant corvids that presumably caused soil to be forced under pans in spite of the fiberglass insulation. In some instances, eagles jumped directly onto the carcass, thereby avoiding the traps, but the activity of feeding usually would cause them to step off the carcass. We later caught all target eagles

involved in failed attempts, with 1 exception where we captured the mate of that bird. We had only 1 suspected case of an eagle escaping from traps, as we found traps pulled from a set in the Cabin territory, and had earlier seen a hatch-year bird flying low and away from the area.

We trapped 7 of 11 eagles before noon, and no eagles were captured that appeared to have hunted successfully (full crop) that day. We captured 7 males and 4 females: All captured birds were adults except 1 juvenile of each sex, 2 subadult males and 1 subadult female. The subadult female was the breeding bird at the Grandview Sand Cliff territory. We usually captured the first bird to appear at a perch in view of the sets, with 1 exception; the Beercase female was present at a perch before the subadult male was captured.

We caught 6 of 10 eagles (1 unknown) by 1 or 2 toes, with the remaining 4 being caught by the tarsus. Seven of 9 (2 unknown) were caught by the left foot. All captures occurred in traps placed near the head or abdomen (2 not recorded). Trap position and capture may be coincidental, as we always placed carcasses with the head or abdomen facing toward a habitual perch.

Spatial use patterns.--Home ranges of territorial eagles were typically centered around the nest, but their size and shape was extremely variable (Table 7; Figs. 32-34). Harmonic mean home ranges varied over more than an order of magnitude from 802 ha - 19,311 ha. Maximum polygons around the most extreme fixes varied by over 2 orders of magnitude. One exceptional range by the female at Grandview Sand Cliff was responsible for most of this variation, but even excluding this range, variation was

considerable. Most ranges were relatively symmetrical, radiating evenly from the nest area. However, the PP&L 119 range was distinctly bimodal, with a heavily used core around the nest and another heavily used core centered around a dense stand of sage preferred for hunting (Fig. 32).

Overlap between the 95% harmonic mean core areas of neighboring eagles was surprisingly extensive (Figs. 33, 34). This is somewhat deceptive. The overlap between the Grandview Sand Cliff and Beercase ranges was certainly an artifact of the large "core" area used by the Grandview female (Fig. 33). Not all of the area within her 95% use area was used, and it was this area that overlapped the Beercase range. Overlap between the Cabin and Black Butte ranges was not due to excessive range inflation from inclusion of excursive points; the Black Butte range was almost entirely included within the Cabin range. However, we never observed the Cabin birds inside the area actually used by the Black Butte birds, and undulating flight displays were common along the boundary between these 2 ranges (Fig. 35). Therefore, overlap in area actually used may be quite small and simply accentuated by the circular method of range estimation inherent in the harmonic mean technique.

Male ($n = 4$) and female ($n = 3$) eagles did not show consistent differences in home range size or travel distances. Males traveled an average of 2,149 m (SD = 1,446) from their nests while females averaged 2,115 m (SD = 582). Maximum travel distances averaged 10,348 m (SD = 5,562) for males and 22,748 m (SD = 24,069) for females. Home ranges determined by the 95% harmonic mean method averaged 4481 ha (SD = 2,599) for males and 10,710 ha

Table 7. Home range characteristics of paired golden eagles determined from radiotelemetry in 1991-1992.

Nesting ^a			Mean distance from: ^b				Max distance from: ^b			Harmonic Mean Home Range ^c				Convex Polygon Home Range ^c				Home Range Shape ^d						
Area	Sex	Burn	N	Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%	Maximum Polygon width (m)	Harmonic Mean				
																				Hr	D	Sk	K	Sp
Brca	M	y	144	2,209	13	2,272	0	16,290	16,290	17,370	51,077	6,878	4,318	476	14,010	2,889	2,076	242	22,990	14.0	3.5	325.0	25.7	101
BlkBt	M	y	224	1,001	26	835	0	2,891	2,891	2,750	1,976	802	552	119	1,075	593	316	162	5,090	26.5	4.9	127.0	36.4	213
Cabin	F	y	119	1,777	22	1,847	0	7,957	7,957	7,401	11,754	3,922	3,015	441	4,655	2,027	631	254	9,932	22.5	4.5	189.8	34.9	174
GVSC	F	n	91	2,785	16	3,364	76	50,520	50,420	49,520	563,128	19,311	4,691	5,386	123,100	462	118	35	83,510	17.0	3.8	280.1	25.9	114
Wildh	F	n	96	1,780	15	1,767	0	9,766	9,766	10,230	23,757	8,898	4,336	488	10,570	2,417	515	194	17,360	15.2	3.7	170.7	38.0	157
Beech	M	y	200	1,217	34	1,355	0	10,500	10,500	9,709	15,481	5,410	2,043	192	5,209	834	200	51	11,100	35.1	5.4	127.0	53.8	344
PL119	M	n	136	4,170	11	4,216	0	11,710	11,710	7,963	8,979	4,835	4,160	503	5,052	4,582	3,423	216	12,220	11.2	3.2	1100.7	24.7	87

^a Nesting areas are abbreviated as follows: Brca - Beercase, BlkBt - Black Butte, GVSC - Grand View Sand Cliff, Wildh - Wildhorse, Beech - Beecham, PL119 - PP&L 119.

^b Distance expressed in m, abbreviated as follows: Hc - harmonic center, Ac - arithmetic activity center.

^c Home ranges expressed in ha.

^d Hr - sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n^2 d^{-1}$), D - dispersion, Sk - skewness, K - kurtosis, Sp - spread.

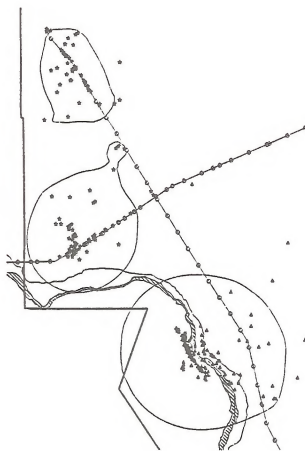


Fig. 32. Home ranges for adult golden eagles throughout the 1991-92 season. Unique locations used each day of observation and the 95% harmonic mean range are plotted for the male from PP&L 119 (bimodal range; stars indicate locations) and the male from Beecham (triangles). Power lines are indicated by thin lines with open circles. The Snake River (hatched area), canyon rim (thin solid line along river), and study area boundary (thick solid line) are included for orientation; north is oriented to the top of the page. All ranges are drawn to the same scale (1:200,000).

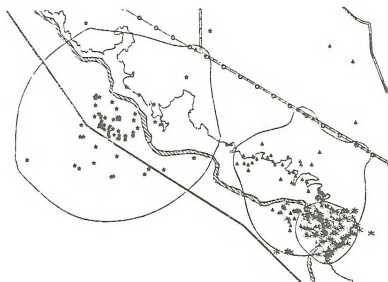


Fig. 33. Home ranges for adult golden eagles throughout the 1991-92 season. Unique locations used each day of observation and the 95% harmonic mean range are plotted for the female from Wildhorse (stars), the female from Cabin (triangles), and the male from Black Butte (asterisks). The Cabin and Black Butte territories are not separated by other nesting pairs of eagles. Land marks are represented as in Fig. 32 with the addition of the OTA boundary (double line) and the range road (alternating solid and open line). North is oriented to the top of the page. All ranges are drawn to the same scale (1:200,000).

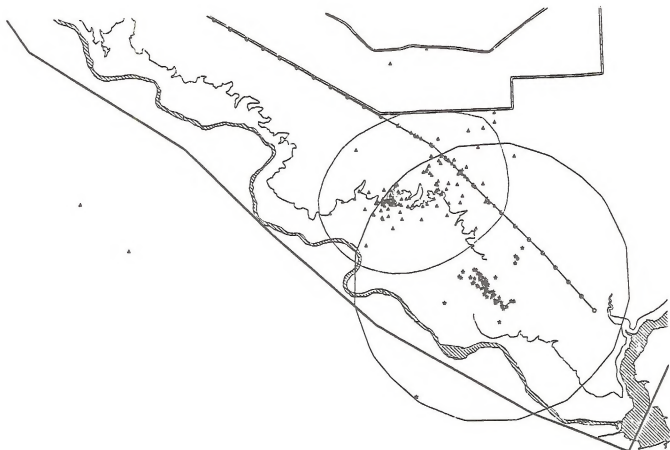


Fig. 34. Home ranges for adult golden eagles throughout the 1991-92 season. Unique locations used each day of observation and the 95% harmonic mean range are plotted for the male from Beercase (triangles) and the female from Grandview Sand Cliff (stars). These ranges were not separated by other nesting pairs of eagles and are also continuous with those ranges plotted in Fig. 33. Landmarks are represented as in Figs. 32 and 33. North is oriented to the top of the page. All ranges are drawn to the same scale (1:200,000).

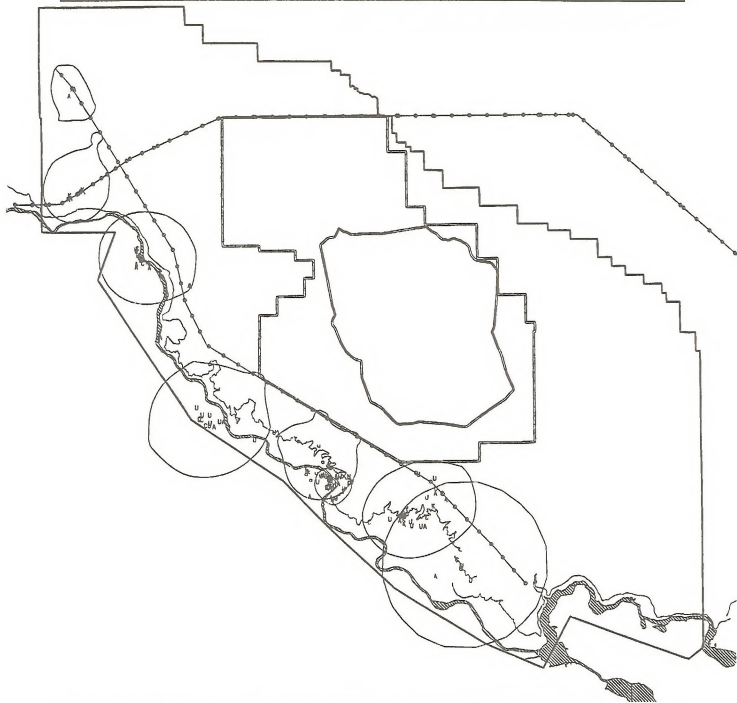


Fig. 35. Home ranges of all eagles studied. Harmonic mean 95% ranges are plotted and the locations of all copulations (c), undulating flights (u), attacks on prey (a), and successful prey captures (k) are plotted. Landmarks are represented as described in Figs. 32 and 33. North is oriented to the top of the page. All ranges are drawn to the same scale (1:300,000).

(SD = 7,853) for females. Polygons around the most distant points averaged 6,337 ha (SD = 5,462) for males and 46,108 ha (SD = 66,742) for females. Large maximum travel distances and home ranges for females primarily reflected the large excursive area used by the Grandview Sand Cliff female after her nest failed (Table 7).

Eagles occupying territories with extensive burned sections tended to range over smaller areas than eagles occupying unburned territories. The average mean travel distance from the nest was 1,551 m (SD = 547) for the 4 eagles occupying burned territories, and 2,912 m (SD = 1,200) for the 3 eagles in unburned territories. Maximum travel distances and home range estimates were less informative because of the inclusion of the Grandview Sand Cliff female with the group occupying unburned territories (Table 7).

Home range size varied considerably between seasons, but extreme individual variation precludes the establishment of many consistent patterns with respect to sex or burn history of the territory (Fig. 36). Females consistently had very small maximum home ranges during incubation, and a steady increase in maximum home range size from winter to early breeding to late breeding (Fig. 36c). Females that were unsuccessful breeders (Grandview Sand Cliff and Wildhorse) ranged farther than the successful breeder (Cabin), and had much larger core-use areas than she did (Fig. 36c,d). Males showed no consistent change in ranging behavior between the seasons (Fig. 36a,b). Males with burned territories had the largest (Beercase) and the smallest (Black Butte) maximum range sizes, but the male in an unburned territory (PP&L 119) had the largest core area (Fig. 36b).

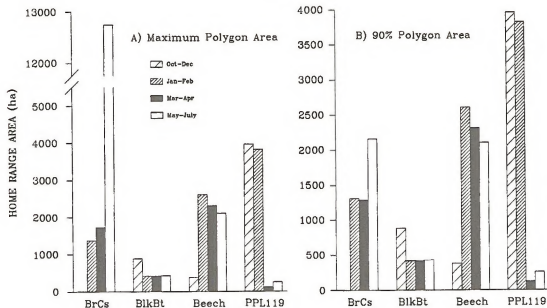
Successful male breeders had the largest (Beercase) and the smallest (PP&L 119) maximum and core ranges.

Despite the high degree of individual variation in eagle home ranges, birds with territories away from the Snake River seemed to have consistently large home ranges. The Beercase male and Grandview Sand Cliff female had the largest ranges, primarily because both took frequent extensive excursions. These 2 eagles differed in every respect (sex, success, burn history), except that they both nested in a portion of the canyon approximately 5 km from the river.

Travel distances.--The locations used for copulation, undulating flight, and hunting were not randomly distributed across the eagle territories. Copulations and undulating flights tended to be closer to the nest than the average travel distance, but hunting locations were farther than the average (Figs. 35, 37). A few exceptions to this generalization are noteworthy. Two eagles copulated at the edges of their ranges (Beercase and Cabin) and therefore had longer than average travel distances to copulations (Fig. 37). One eagle undulated at the edge of the range (Wildhorse) and therefore had a greater than average travel distance to undulating flight locations (Fig. 37).

Travel distances tended to be small during the winter, smallest during early breeding, and large after nestlings were well developed (Fig. 38). Females all showed significant changes in travel distance across seasons, but only 2 of 4 male changes were significant (Table 8). Travel distances did not vary from morning to evening (Table 8). However, 1 female (Grandview Sand Cliff)

MALES



FEMALES

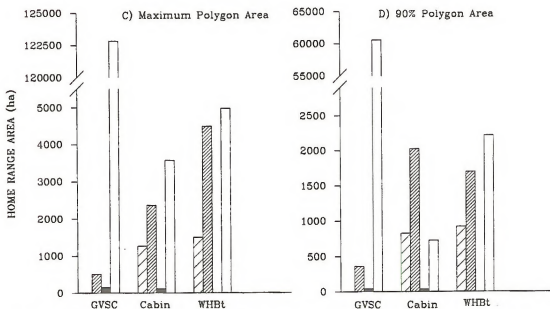


Fig. 36. Maximum home range sizes and 90% core-use areas for breeding male ($n = 4$) and female ($n = 3$) golden eagles during 4 time periods. Territories are abbreviated as follows: BrCs = Beercase, BlkBt = Black Butte, Beech = Beecham, PL119 = PP&L 119, GVSC = Grandview Sand Cliff, Cabin = Cabin, and WildH = Wildhorse.

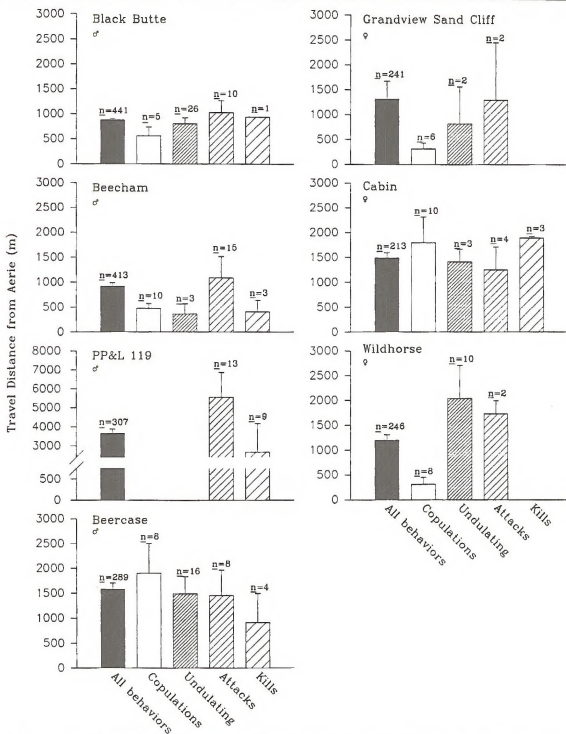


Fig. 37. Travel distances of adult golden eagles to locations where copulations, undulating flights, attacks and kills were observed. Average travel distance to all locations is plotted first for each bird.

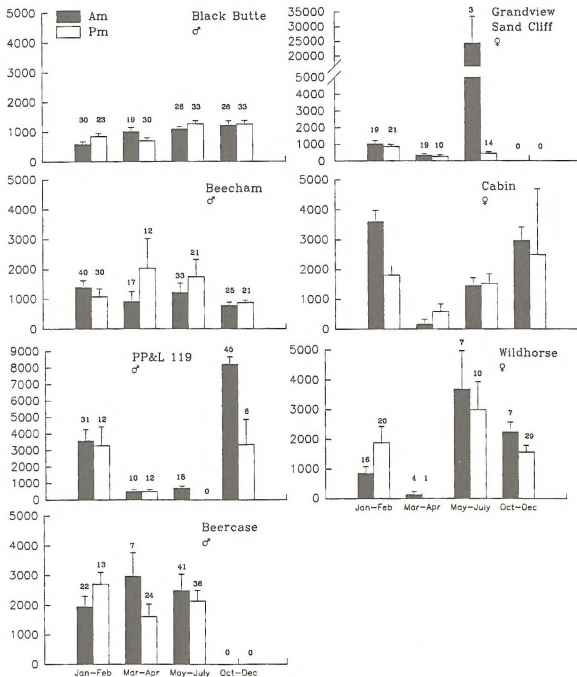


Fig. 38. Travel distances of adult golden eagles throughout the annual cycle and during AM (sunrise-1300) versus PM (1300-sunset) observations.

Table 8. Influence of season (see Fig. 36 for definitions) and time of day (2 periods: sunrise-1300, 1300-sunset) on distance traveled from the aerie by breeding golden eagles. Only unique points visited within a day are analyzed.

Nesting Area	Sex	Season			Interaction			Time		
		F	DF	P	F	DF	P	F	DF	P
Beercase	M	0.0	2,137	1.0				0.4	1,137	0.53
Black Butte	M	9.3	3,212	<0.001				0.3	1,212	0.57
Cabin	F	7.2	3,105	<0.001				0.9	1,105	0.34
Grandview Sand Cliff	F				92.7	2,80	<0.001			
Wildhorse	F	5.0	3,86	0.003				0.0	1,86	0.86
Beecham	M	1.4	3,191	0.25				1.9	1,191	0.17
PP&L 119	M	41.7	3,130	<0.001				---	-----	---

traveled to extremely distant points during the late breeding season and during the afternoon. As a result, the interaction between season and time was significant for her (Table 8).

Use of the OTA.--Eagles holding territories in the canyon rarely traveled into the OTA (Figs. 32, 33, 34). We observed eagles inside the OTA boundaries 9 times, and inside the Range Road once. However, the "Big Baja" power line that forms a portion of the western boundary of the OTA was used often during hunting forays and was a common roosting area.

Foraging behavior.--We observed 80 hunting forays (flight involving 1 or more strikes at prey) and 27 successful prey captures (Table 9). Black-tailed jackrabbits were the principal prey item captured (9 jackrabbits and 1 unidentified rabbit = 37% of prey captures). Six Townsend's ground squirrels (22.2% of captures), 1 pigeon, 1

duck, and 1 unidentified snake were also captured. Unidentified prey items were captured 29.6% ($n = 8$) of the time. All eagles hunted jackrabbits, but individuals varied in their use of secondary prey. The PP&L 119 male caught the most Townsend's ground squirrels; he often sat on a power line tower next to his nest that was surrounded by ground squirrels and dropped from the pole to catch squirrels. Two males that made extensive use of the canyon (Beecham and Black Butte) were responsible for most of the attacks and captures on pigeons and waterfowl.

Habitat types were not used equally for hunting (Fig. 39). Moderately disturbed shadscale, cliff faces, and riparian areas were the most commonly hunted habitats. However, hunting success in these 2 habitats differed radically; few hunts along cliffs were successful, most kills occurred in riparian and moderately disturbed shadscale habitats. Undisturbed greasewood and

Table 9. Golden eagle foraging summary. Habitat codes (Knick, this volume) were used for field classification of habitat type. Numbers in parentheses refer to the number of that prey type that was chased or taken by hunting golden eagles. Number of strikes refers to the total number of strikes for all forays in the given habitat type ("?" indicates that the number of strikes was unknown for at least 1 foray).

Territory	Sex	Habitat (Code)	Hunting Attempts			Hunting Success	
			# Forays	# Strikes	Prey type chased (#)*	# Kills	Prey type taken(#)*
Beercase	M	Agriculture	2	1?	Unknown(1) Waterfowl(1)	0	
		Russian Thistle(ID4)	1	1	Unknown(1)	0	
		Sagebrush(A1)	1	?	BTJack(1)	1	BTJack(1)
		Shadscale(A2)	3	5?	Unknown(2) BTJack(1)	0	
		Shadscale(IB2)	5	2?	Unknown(5)	4	Unknown(4)
		Spiny Hopsage(A6)	1	1	Unknown(1)	1	Unknown(1)
		Spiny Hopsage(IB9)	1	?	BTJack(1)	1	BTJack(1)
		Shadscale(A1)	1	3	Unknown(1)	0	
		Cliff	11	21	Pigeon(1)	1	Pigeon(1)
		Rabbitbrush(A7)	1	1	Unknown(1)	0	
Beecham	M	Riparian	4	4?	Unknown(2) Rabbit(1) Waterfowl(1)	2	Unknown(1) Rabbit(1)
		Sagebrush(A1)	1	3	Unknown(1)	0	
		Shadscale(IB2)	1	5	BJack(1)	1	BJack(1)
	F	Riparian	1	1	Waterfowl(1)	1	Waterfowl(1)
		Saltbush(A5)	1	1	Raven(1)	0	
		Cliff	3	4	Unknown(1) Pigeon(2)	0	
Black Butte	M	Greasewood(A4)	1	1	Unknown(1)	0	
		Native Grasses(A1)	1	1	Unknown(1)	0	
		Riparian	3	4	Unknown(2) Waterfowl(1)	0	
		Shadscale(A2)	1	1	BTJack(1)	1	BTJack(1)
		Shadscale(IB2)	1	?	Unknown(1)	1	Unknown(1)
		Greasewood(A4)	4	8	Unknown(1) BTJack(2)	2	BTJack(2)
Cabin	M	Greasewood(IB4)	1	1	BTJack(1)	1	BTJack(1)
		Shadscale(IB2)	1	1	Unknown(1)	0	
		Agriculture	1	1	Unknown(1)	0	
Grandview Sand Cliff	F	Shadscale(A2)	2	5	Unknown(1)	0	
		Shadscale(IB2)	2	3	Unknown(1) TGS(1)	1	Unknown(1) TGS(1)
		Agriculture	1	1	TGS(1)	1	TGS(1)
PP&L 119	M	Cheatgrass/Native(IB1)	2	2	Unknown(2)	0	
		Cheatgrass(IB2)	3	3	Unknown(1) TGS(2)	2	Unknown(1) TGS(1)
		Cliff	1	1	Pigeon(1)	0	
		Sagebrush(A1)	4	8	Unknown(4)	0	
		Sagebrush(IB1)	6	27?	Unknown(3) BTJack(3)	2	BTJack(2)
		Shadscale(IB2)	3	3	TGS(3)	3	TGS(3)
		Winterfat(A3)	1	1	TGS(1)	1	TGS(1)
		Winterfat(IB3)	1	1	TGS(1)	0	
		Shadscale(IB2)	1	3	Raven(1)	0	
		Sagebrush(A1)	1	?	Snake(1)	1	Snake(1)

* Prey types abbreviated as followed: TGS-Townsend's ground squirrel, BTJack-black-tailed jackrabbit

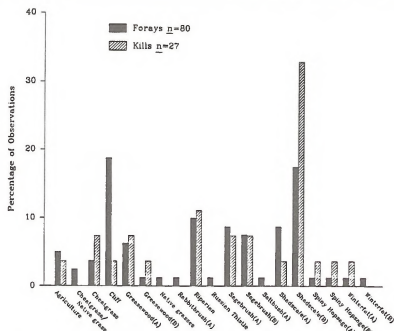


Fig. 39. Habitat types where breeding golden eagles were observed hunting (Forays) and capturing (Kills) prey in 1991-1992. A or B after a habitat type refers to low and moderate disturbance respectively as defined by Knick (this volume).

cheatgrass were hunted relatively infrequently, but produced a high percentage of successful captures.

■ DISCUSSION

Prairie Falcon Ranging Habits

Effects of radio transmitters.--There were no detectable differences in falcon behavior or productivity associated with instrumentation in either 1991 or 1992. The key to minimizing effects appears to lie with the capture and processing of birds rather than with the transmitter itself. Transmitter shapes varied from a cylinder in 1991 to a flat rectangle in 1992; differences in

aerodynamics appeared inconsequential to the falcons. However, the timing of capture and the decision to instrument or release particular individuals may determine the impact of instrumentation. The tendency for females to fail at higher rates than males in 1991 was not observed in 1992, presumably because we avoided capturing females before incubation and we released 1 female captured at this time that appeared to be forming an egg (her mate was subsequently captured and their nesting attempt was successful; Swan I Draw Mouth DS).

Comparison of 1992 and 1991.--Abiotic and biotic factors important to raptors differed in subtle ways in 1991 and 1992. Populations of the major prey item,

much of the variation probably reflected variation in habitat among territories (Collopy and Edwards 1989) and the reality that long-lived, territorial, permanent residents develop individual preferences.

The potential importance of habitat composition to home range size was illustrated by the consistently large home ranges of the 2 eagles that nested farthest from the river (Fig. 34). Earlier studies of eagle ranging habits in the SRBOPA also identified relatively large territories in this part of the canyon (Grand View Feedlot Territory; Dunstan et al. 1978, Collopy and Edwards 1989). Territories in this part of the canyon have little greasewood, riparian, and dense sage habitat, vegetation associated with the greatest densities of black-tailed jackrabbits (Smith and Nydegger 1985).

Home ranges reported in this study were larger than those reported previously in the SRBOPA. Previous territories were calculated using maximum polygons and ranged from 1,161 - 4,898 ha (Collopy and Edwards 1989) and from 1,700 - 5,030 ha (Dunstan et al. 1978). Four of the eagles we studied had similar ranges, but the other 3 had much larger ranges. These 3 birds had ranges larger than the previously published maximum (9,324 ha in southern California; Dixon 1937). The larger home ranges determined in our study were due to long excursive trips out of the usual home range. These were apparently less common in the late 1970's or not recorded because of the difficulty associated with keeping widely roaming eagles in view. However, documenting such travels is important because territories with poor quality habitat in their core-use areas may be able to sustain successful breeding if suitable habitat is within the excursive range.

Larger territory size observed in 1992 relative to the mid-1970's may also indicate a general degradation of the habitat which has forced eagles to gradually require more space. This can be tested when complete vegetation maps are available, but current evidence does not support this idea. Four territories studied in 1992 were also studied by Dunstan et al. (1978); all suffered habitat degradation in the form of extensive burning, but only 2 increased in size appreciably from 1977-78 to 1992 (Cabin and Grand View Feedlot/Beercase); the other 2 decreased in size (Black Butte and Beecham).

Previous studies of eagle ranging habits in the SRBOPA did not detect an increase in space use as the nesting cycle proceeded (Dunstan et al. 1978). This was probably because detailed observations were not made on radio-tagged pairs after their nesting attempt failed. The females that we observed, especially those that failed to fledge young increased their space use throughout the nesting cycle (Figs. 32, 38, Table 8). Increased space requirements do not appear to simply be a response to increased demands posed by developing nestlings. Instead, females that failed to fledge young appear to become somewhat nomadic, perhaps searching for better foraging conditions outside their core-use area. This again suggests that management decisions should consider the maximum range rather than the core range utilized by raptors.

Golden eagles hunted in a wide variety of habitats, but 6 were hunted most frequently (Fig. 39; cliff, greasewood A, riparian, sagebrush A, B, and Shadscale B). Moderately disturbed shadscale and riparian habitats appeared especially important to eagles because together they accounted for

nearly half of the locations where we observed eagles make kills. The importance of shadscale was not noted in previous studies of eagle foraging habitats in the SRBOPA. This habitat certainly was used heavily in 1992; however, until a complete vegetation map is available, we cannot determine if it was used out of proportion to its abundance.

Is there an effect of military training?

Prairie falcons.--Prairie falcons are a model species to study the potential effects of military training because their extensive ranging habits often bring them into areas where training occurs. However, this species rarely nests in the training area and therefore the influence of military training is restricted to effects on foraging behavior and possibly post-fledging dispersal (McFadzen and Marzluff, this volume).

Military training that involves firing of tanks, missiles, artillery, and machine guns significantly influenced the ranging habits and hunting behavior of prairie falcons. These raptors were less abundant on training ranges in the OTA during firing than non-firing days (Fig. 25). This was significant during the second observation period (June), which coincides with the time that falcons utilize the OTA most heavily (Fig. 3). This was also the period of extremely heavy military training in 1992 (Operation Bold Shift). On firing days, falcons in the training range area appeared to behave typically; they primarily flew low to the ground and perched (Fig. 29). However, these behaviors were less common than on non-firing days, and high altitude traveling flights were more common than on non-firing days (Fig. 30).

These local responses to military training may explain why distances traveled by radio-tagged falcons were significantly longer on firing days than on non-firing days (Fig. 15). If activity on the training ranges influences falcon travel from the aerie as it does for a variety of raptors in Colorado (Andersen et al. 1990), then birds in the OTA shadow should be influenced more than birds west of the shadow. This appears to be the case (Fig. 15). However, this tidy summary has a problem: increased travel by birds in the OTA shadow on firing days may not be directly related to avoidance of the OTA or avoidance of the area inside the Range Road. We located birds in these areas with equal frequency regardless of military activity. Four factors probably account for this discrepancy: (1) use of the OTA by tagged falcons was minimal in 1992; (2) falcons avoided ranges that were actively firing, but on any given day not all ranges are firing. Therefore, falcons can use the interior of the Range Road on firing days and still avoid ranges where military training is occurring; (3) falcons using ranges with ongoing military activity are primarily traveling through the area (Fig. 30), and therefore, we can still obtain telemetry locations on them; (4) the disturbance that causes falcons to increase their travel distance from the canyon is not activity on the firing ranges per se, but the associated increase in activity away from the ranges.

We suspect that the increased peripheral disturbance associated with activity on the firing ranges is a key factor in explaining why falcons nesting near the OTA increased travel distances on training days relative to non-training days. Military travel along the dirt trails and "Big Baja" power line road in the western sections of the OTA increased

substantially during training periods, which could have displaced foraging falcons and forced them to hunt in locations more distant from their aeries. Female falcons showed the greatest increase in travel distance on firing days (Fig. 15), but paradoxically also tended to spend a greater percentage of time close to their nests on firing days relative to non-firing days (Table 4). The typical travel distance for females on non-firing days was 2.5-3.5 km from their nest, very near the "Big Baja" power line. On firing days, this distance doubled. We hypothesize that females were flushed from perches on the power line by military vehicles and then either flew down the power line to an undisturbed perch or returned to their nest. This response would produce increased travel distances and increased time at the nest. Males showed less of a difference in travel on firing versus non-firing days possibly because their average foraging range was large and beyond the power line area. Therefore, they were less likely to be flushed by traffic and could relocate to another portion of their usual foraging area if they were flushed.

Changes in ranging habits in response to military training did not affect the amount of food nestling falcons received (Fig. 19, Table 4). Parents appeared able to capture prey during their longer forays from the nest on firing days, and prey delivery rates of birds nesting in the OTA shadow were nearly equal to those exhibited by birds west of the shadow despite the significantly larger home ranges of shadow birds. One way that falcons in the OTA shadow maintained high prey delivery rates was to increase the range of food items in their diet relative to birds west of the OTA. Falcons west of the OTA specialized on mammals, especially Townsend's ground squirrels, but falcons in

the OTA shadow consistently included a greater variety of food items in their diets (Fig. 20). Use of a wider variety of foods is expected when a raptor's primary prey item is in low abundance (Steenhof and Kochert 1988).

Although nestlings received food at a similar rate on firing and non-firing days, and at OTA compared to western nests, the mechanics of prey delivery appeared fundamentally different under these conditions. At nesting areas west of the OTA, males had the highest recorded delivery rates of prey items to the territory (Fig. 19a). Many of these items were taken directly to the nestlings, but many were cached. Females west of the OTA recovered cached food items and delivered them to their nestlings (Fig. 19c). This allowed them to maintain very high prey delivery rates to their nestlings (Fig. 19b) without bringing much prey into the territory (Fig. 19a). In contrast, males in the OTA shadow brought fewer prey items into the territory (Fig. 19a), and most of these went straight to the nestlings; caching was rare (Fig. 19c). Females in the OTA shadow received few prey items from caches and therefore exhibited delivery rates to the nestlings that were very similar to the amount of food they brought into the territory. The inability of males in the OTA shadow to provide sufficient prey appeared to force females to bring more prey into the territory than females west of the OTA. These differences were especially pronounced when the nestlings were < 21 days old. A similar pattern was noted by Holthuijzen (1990).

The ability to sequester enough food to cache at territories west of the OTA shadow may also allow males to reduce the time they spend hunting (Holthuijzen 1990). In

the shadow, parents began bringing fresh food items into the territory 2 hrs before parents west of the shadow (Fig. 21a,e). Both parents delivered items to the nest during the first 2 hrs after sunrise, but parents we observed west of the shadow used cached reserves for this purpose; parents in the shadow may have needed to obtain fresh items to supplement their meager caches.

Parent falcons we observed in the OTA shadow adjusted their behavior to the age of their nestlings differently than parents we observed west of the shadow. Prey deliveries increased and caches decreased as nestlings in the OTA shadow grew, but these rates were less strongly correlated with nestling age west of the shadow (Table 6). Female attendance in the territory also was most closely correlated with nestling age at nesting areas in the OTA shadow (Table 6). Females in the OTA shadow reduced attendance of old nestlings, probably because they were forced to hunt more to supplement the limited delivery rates made by their mates.

Obtaining sufficient food to feed nestlings was not a factor limiting productivity in 1991 and 1992. Therefore, despite differences in ranging habits, birds in the OTA shadow exhibited fledging success (Steenhof et al. 1991, Lehman et al. this volume) and post-fledging productivity (McFadzen and Marzluff, this volume) similar to birds west of the shadow. However, the differences in caching and parental attendance suggest that parents nesting in the OTA shadow may be compromised when prey abundance drops. They have managed to provide sufficient amounts of prey during the relatively productive prey years of 1991 and 1992.

However, in a poor prey year successful provisioning of nestlings may be less likely, and as was seen during a previous prey crash in the study area, productivity may decline (U.S. Dep. Inter. 1979).

Increased ranging habits, poor cache balances, and use of prey other than Townsend's ground squirrels suggest that falcons nesting in the OTA shadow have less prey available to them than falcons nesting west of the shadow. This is not to say that military training is responsible for these differences. As indicated in the introduction, climatic and vegetative differences also may exist between the OTA shadow and the western study area. Holthuijzen (1990) compared prairie falcon nesting behavior in 2 areas having ecological differences similar to those found between the OTA and the western site. He found that falcons in the poor prey area used a wide variety of prey items, such as we observed in falcons using the OTA shadow. Military training and ecological differences between the OTA and the western area are both likely to influence falcon ranging habits; the documented increases in falcon travel distances are probably accentuated by historical differences between the OTA and the western area.

Other raptors.--Buteos, eagles, northern harriers, and owls observed on the firing ranges exhibited the same aversions to firing as prairie falcons did (Fig. 22). These species were most common on the ranges early in the season (May), and differences in abundance on firing versus non-firing days was most dramatic during the time of heaviest military training (June). Few raptors used the firing ranges late in the season, and therefore statistical assessment

of the small change in abundance with respect to firing was not significant.

Changes in behavior by species other than prairie falcons were less closely related to firing activity. Buteos, eagles, and harriers tended to perch less on firing than non-firing days, and their primary flight style (soaring and low flight, respectively) was seen less on firing than non-firing days (Figs. 29, 30). Observations of owls were infrequent, especially on firing days, but they appeared to greatly reduce perching and low flights on days with firing.

Changes in the use of ranges by these raptors on firing days may have more significant effects on their productivity than they had on prairie falcons. Harriers, owls, and ferruginous hawks are of special concern because individuals using the firing ranges presumably nest near the range. Local displacements for these birds could seriously disrupt breeding. Ferruginous and Swainson's hawks (*Buteo swainsoni*) occasionally abandon their territories in response to military activity (Andersen et al. 1990). Most buteos and eagles we observed were nonbreeders (golden eagles, rough-legged hawks, and occasional groups of Swainson's hawks) or breeders from presumably distant nesting areas (adult red-tailed [*Buteo jamaicensis*] and Swainson's hawks). These species may be displaced from foraging areas during firing, but they should be affected in a manner similar to prairie falcons; their wide ranging habits should allow them to find prey elsewhere in abundant prey years.

Golden eagles breeding in the canyon occasionally may be susceptible to disturbance associated with military training in the OTA. These birds rarely used the

OTA. However, they hunted in the western portion of the OTA and may be vulnerable to disturbance along the power line road where they often perch and roost.

Effects of Weather

The variable climate of the Great Basin Desert has pronounced effects on raptor behavior. Activity of prairie falcons and other raptors using the firing ranges typically peaked when temperatures and wind speeds were low to moderate (Figs. 2, 4, 23, 24). This is not particularly surprising, but the relationships between raptor abundance and weather mandate that weather factors be taken into account in all comparisons between abundance and military activities. Failure to account for prevailing weather conditions while observations are made can lead to misleading conclusions. For example, a comparison of raptor abundance on days with tank, artillery, and small arms firing to abundance on days without firing yielded highly significant results when weather was not taken into account (fewer birds present on firing days, $P = 0.03$). But, taking temperature into account by including it as a covariate in the analysis lowered the significance considerably ($P = 0.14$), and including temperature and wind speed as covariates completely obliterated the relationship between firing and raptor abundance ($P = 0.45$).

Management Hypotheses

We offer the following discussion of potential impacts and recommendations for ways to minimize military training effects on raptors in the SRBOPA. The hypotheses are quite preliminary because they relate primarily to birds that nest in the canyon and forage on the benchlands, and they are based

on observations when populations of Townsend's ground squirrels were abundant. They are not intended to be management recommendations, but as points to focus future observations into more direct tests of perceived human effects.

1. Firing activity on the training ranges had the localized effect of reducing the number of raptors on the range and modifying their behavior. This was most pronounced during May and June when military training was most intense and large numbers of raptors use the ranges (Fig. 22). We hypothesize that this effect could be minimized by restricting firing on ranges during these months. In particular, firing should be concentrated in the mid-day lull of raptor activity (approximately 7-11 hr after sunrise; Figs. 5,6,21). Avoidance of firing early in the morning may be especially important because falcons nesting in the OTA shadow typically have few cached food items to feed nestlings early in the morning and therefore begin foraging earlier than birds west of the shadow.
2. Military activity peripheral to the firing ranges may substantially affect the ranging habits of raptors nesting in the OTA shadow. Limited observations at bivouac sites in 1992 suggest that bivouacs may reduce raptor activity in the immediate area similar to the reductions associated with firing on ranges. Disturbance of foraging raptors in the western portion of the OTA, especially along the "Big Baja" power line, may be a primary reason that falcons in the OTA shadow expand their foraging areas on firing versus non-firing days. The power line is also important

to golden eagles that nest in the canyon. Direct observations are needed to critically assess these impacts.

3. Space requirements of raptors appeared to be highly individualistic. However, failed breeders and non-breeders had much larger home ranges than successful breeders (see also Squires et al. 1993). Large excursive areas may be necessary to allow successful reproduction in territories that include poor habitat. Any buffer areas established around the canyon should be based on the maximum home range size of individuals within a species rather than the average home range size.
4. Ways to ensure that disturbance within the canyon will be kept to a minimum should be explored. Some golden eagles (e.g., Black Butte) spent virtually all of their time inside the canyon, and female prairie falcons also rarely ventured out of the canyon for most of the breeding season. Disturbance at nesting territories and foraging areas within the canyon may be more detrimental to raptor populations than the current disturbance inside the Range Road.

■ PLANS FOR NEXT YEAR

Next year (1993) holds promise for being a key year to assess any potential effects of military training on raptors because we suspect the population of Townsend's ground squirrels will crash to very low levels. Therefore, we will continue to radio tag and monitor prairie falcons and golden eagles as we did in 1992. We propose to follow raptors, including tagged prairie falcons and golden eagles, to determine where they are

making kills and test the hypothesis that disturbance peripheral to the firing ranges influences ranging behavior of raptors. These observations will be conducted primarily in the western part of the OTA and along the power line. We propose reducing observations on firing ranges to accomplish this objective; local aversions of raptors to firing have been consistent in 1991 and 1992, are significant, and require little further study.

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Appendix A: Band combinations and physical characteristics of adult Prairie Falcons captured in the SRBOPA, 1992.

Date	Territory	Band No.	Color Band		Sex	Mass(g)	%Crop	Wing (mm)		Toe Pad(mm)	Radio Freq.	Time Held (min)	No. Fledged
			color ^a	leg code				span	chord				
17 MAR	PRIEST RAPIDS II	*816-70149	BL	L 1/U	M	603	0-25	968	322	79.0	164.665	53	5
17 MAR	UNKNOWN (PRIEST RAPIDS I)	1807-01296	BK	R E/8	F	954	-	0	350	-	b	47	-
17 MAR	PEREGRINE CLIFF	*816-70165	BL	L 3/A	M	580	0-25	956	311	77.0	164.727	74	4 ^d
17 MAR	CATTELGUARD NARROWS	816-74851	BK	R 4/0	M	537	0-25	946	301	76.0	164.815 ^f	77	-
17 MAR	HALVERSON SPRING	816-74852	BK	R 4/1	M	527	0-25	1,002	306	79.0	164.036 ^g	48	2
18 MAR	CATTELGUARD UPSTREAM	816-74853	BK	R 4/2	M	610	0-25	982	301	76.0	164.585	40	5
18 MAR	SLICE DRAW	1807-38661	BK	R C/G	F	978	0-25	1,106	343	88.0	164.526	65	5
19 MAR	HELL HOLE GATE	816-74854	BK	R 4/3	M	607	0-25	982	299	81.0	164.565	61	1 ^g
19 MAR	FALCON FLATS ENGINE	816-70266	BK	R 6/C	M	540	0-25	954	295	75.5	164.707	142	4
20 MAR	OGDEN GE77	1807-38662	BK	R 9/X	F	1,047	0-25	1,102	342	94.0	164.805	57	0
20 MAR	FANG DOWNSTREAM	816-74855	BK	R 4/4	M	575	0-25	952	306	77.0	164.368	70	6
21 MAR	BLACK BUTTE FERRUG	816-70267	BK	R 6/2	M	565	0-25	954	311	79.2	164.465	117	4
23 MAR	MASSACRE FACE	1807-38663	BK	R G/7	F	1,133	0-25	1,090	346	93.6	164.875	98	5
25 MAR	CSJ	*816-74715	BK	L Q/E	M	573	0-25	884	292	76.5	-	30	-
26 MAR	UNKNOWN (RED TRAIL)	1807-38651	BK	R M/5	F	952	0-25	1,124	354	94.0	164.185	127	-
26 MAR	SWAN I DRAW MOUTH DS	1807-38664	BK	R 9/2	F	1,035	0-25	1,130	344	88.0	-	25	2 ^g
26 MAR	SWAN I DRAW MOUTH	1807-38663	BK	R 9/Y	F	955	0-25	1,088	350	88.0	164.305	67	4
27 MAR	BEERCASE DRAW	816-70268	BK	R 6/3	M	604	0-25	916	310	78.3	164.825	101	4
30 MAR	HENDERSON DRAW	1807-01297	BK	R 6/W	F	959	0-25	1,090	348	92.6	164.428	68	4 ^d
30 MAR	SWAN I DRAW WEST	1807-38665	BK	R C/S	F	905	0-25	1,068	345	90.0	164.835	67	5
30 MAR	SWAN I DRAW MOUTH DS	816-74856	BK	R 4/5	M	575	0-25	966	303	77.0	164.325	68	2
31 MAR	THIRST DRAW DOWNSTREAM	*816-74716	BK	L O/G	M	535	0-25	942	296	75.5	164.845	88	5
01 APR	BEERCASE DOWNSTREAM	1807-38652	BK	R L/O	F	930	0-25	1,068	348	93.2	164.485	130	3 ^h
01 APR	FALCON FLATS CAVE EAST	816-74857	BK	R 4/C	M	545	0-25	990	317	78.5	164.445	81	3 ^h
01 APR	DEDICATION POINT	1807-38666	BK	R C/D	F	985	0-25	1,120	349	91.0	164.265	58	4
07 APR	OGDEN ROCK	1807-38668	BK	R C/K	F	870	0-25	1,110	345	92.0	164.815	67	4
08 APR	TOM DRAW	1807-01299	BK	R 9/W	F	892	0-25	1,008	351	91.0	164.855	102	5
14 APR	NAHAS	816-74859	BK	R 5/R	M	587	0-25	936	298	79.0	164.605	82	0
08 APR	TICK III	816-70260	BK	R 6/D	M	553	0-25	955	306	75.6	164.282	88	4
14 APR	SLIDE II	816-70261	BK	R 6/5	M	516	0-25	939	303	76.1	164.385	90	5
08 APR	WEST POINT	816-74858	BK	R 4/6	M	560	0-25	980	305	82.0	164.345	60	4
07 APR	BALLS PT UPSTREAM	816-70269	BK	R 6/4	M	564	0-25	944	301	77.5	164.867	89	0
03 APR	PETROGLYPHS	1807-01298	BK	R K/O	F	987	0-25	1,094	346	92.0	164.826	65	5
06 APR	MOTHER GIANT UPSTREAM	1807-38667	BK	R C/C	F	990	25-50	1,050	342	93.0	164.405	85	4 ^d
12 MAY	TADPOLE LAKE	816-70293	BK	R 6/9	M	533	0-25	910	300	77.7	164.085	110	0
27 APR	HALVERSON SPRING	1807-01300	BK	R H/2	F	840	0-25	1,066	330	89.2	164.036	80	2
20 APR	RATTLESNAKE CANYON	816-70292	BK	R 6/6	M	491	0-25	904	296	70.8	164.890	86	-

^a * denotes previously banded individuals.^b Color: BL - Blue, BK - Black^c Non-targeted bird captured.^d Minimum fledging count due to inability to obtain a positive complete count.^e Bird removed transmitter (transmitter subsequently applied to different bird); productivity not monitored.^f Captured to remove transmitter applied in 1991; productivity not monitored.^g Bird not instrumented due to gravid condition.^h Breeding success undetermined.

Appendix B: Band combinations and physical characteristics of golden eagles captured in the SRBOPA form February 1991 - June 1992.*

Date	Trap site or nesting area	Band No.	Time Held (hr:min)	Sex	Age	Mass (g)	%Crop	Wing			Body Circ.	Bill Depth	Culmen	Head Length	Hallux	Footpad	Treatment N/B/P ^a	Freq.
								span	width	chord								
11 Feb 91	Pl. Valley Rd H-poles	629-18131	1:29	-	Subad	3,280	0-25	1,952	346	568	510	-	-	-	-	-	B	4,830
19 Feb 91	PP&L 119	629-02630*	0:55	M	Ad	3,740	0-25	2,070	344	596	519	-	-	-	-	-	B	4,820
26 Oct 91	PP&L 119	629-02630*	1:35	M	Ad	3,550	0-25	1,994	341	595	558	28.8	44.3	117.9	52.9	137.0	B	4,820
31 Jul 91	PP&L 119	629-18132	2:35	F	Juv	4,090	0-25	1,908	351	623	576	29.2	44.5	123.8	53.0	-	B	4,570
14 Oct 91	Wildhorse	629-18133	1:33	F	Ad	4,430	0-25	2,026	373	605	512	31.0	45.1	123.8	63.7	-	B	4,890
04 Nov 91	Black Butte	629-18134	1:05	M	Juv	3,750	0-25	1,860	357	595	485	28.5	41.5	116.8	49.4	-	N	-
12 Nov 91	Black Butte	629-18135	2:01	M	Ad	3,995	75-99	1,920	350	578	517	28.2	48.7	113.6	48.7	130.9	B	4,590
15 Nov 91	Beercase	629-18136	1:58	M	Subad	3,400	0-25	1,988	338	588	533	28.0	41.6	114.8	47.5	130.4	B	4,540
22 Nov 91	Beecham	629-18137	1:55	M	Ad	3,750	25-50	1,836	327	571	536	27.8	42.3	114.7	51.6	126.4	B	4,600
06 Dec 91	Cabin	629-18138	2:13	F	Ad	4,750	0-25	2,194	380	643	577	30.3	45.3	126.1	59.6	144.7	B	4,630
17 Dec 91	Grandview Sand Cliff	629-18139	1:59	F	Subad	4,370	0-25	2,088	376	630	-	30.1	46.5	122.7	54.9	146.7	B	4,660
15 Jan 92	Beercase	629-18140	0:39	M	Subad	4,020	75-99	1,894	355	575	450	28.6	40.4	116.5	49.2	127.7	N	-
16 Jan 92	Beercase	629-18141	2:02	M	Ad	3,900	0-25	1,930	332	564	536	27.7	49.7	115.3	48.0	125.4	B	4,710
03 Jun 92	Cabin	629-18142	2:00	-	Nesting	3,800	-	-	-	-	-	25.8	-	-	-	131.8	P ^a	-
03 Jun 92	Cabin	629-18143	2:00	-	Nesting	3,500	-	-	-	-	-	25.9	-	-	-	129.7	P ^a	-
03 Jun 92	Beercase	629-18144	1:00	-	Nesting	3,200	-	-	-	-	-	25.7	-	-	-	131.5	P ⁱ	-
03 Jun 92	Beercase	629-18145	1:00	-	Nesting	4,100	-	-	-	-	-	27.6	-	-	-	145.2	P ^o	-

* All measurements expressed in millimeters

^a * denotes a previously banded individual^b Treatment: B = radio backpack N = none P = patagial tag^c Patagial marker code: C1 on red tag, left wing^d Patagial marker code: C2 on red tag, left wing^e Patagial marker code: B1 on blue tag, left wing^f Patagial marker code: B2 on blue tag, left wing

Appendix C: Golden eagle trapping summary, 1991-92.

Date	Trap site or nesting area	USFWS Band	Radio freq.	Sex	Age	Attempts (days/area)	Capture Time	Time at set before capture	Capture characteristics Trap position Leg/Toe		Non-target captures/territory
31 Jul 91	PP&L 119	629-18132	4.570	F	Imm	5 ^a	1345	Unknown	belly	left/3rd	raven
28 Oct 91	PP&L 119	629-02630	4.620	M	Ad	"	0910	seconds	head	left?/2nd,3rd	.
14 Oct 91	Wildhorse	629-18133	4.690	F	Ad	2	0838	seconds	belly	left/3rd	none ^a
04 Nov 91	Black Butte	629-18134	.	M	Im	5 ^b	0850	seconds	?	?/toe	maggie
12 Nov 91	Black Butte	629-18135	4.590	M	Ad	"	1115	13 mins. ^d	head	left/tarsus	.
15 Nov 91	Beercase	629-18136	4.540	M	Subad	9	1032	seconds	head	left/tarsus	5 ravens ^a
15 Jan 92	Beercase	629-18140	.	M	Subad	"	1235	30 mins. ^a	head	?	.
16 Jan 92	Beercase	629-18141	4.710	M	Ad	"	0901	3 mins. ^f	belly	right/2nd	.
22 Nov 91	Beecham	629-18137	4.600	M	Ad	2	0825	few mins.	head	left/tarsus	maggie
06 Dec 91	Cabin	629-18138	4.630	F	Ad	3 ^g	1335	seconds	head	right/tarsus	none
17 Dec 91	Grandview Sand Cliff	629-18139	4.560	F	Subad	1	1358	seconds	?	left/1st	raven

All trap attempts began at least 30 mins before sunrise.

^a Trapped 1 rainy day, caught raven, both adult and immature females fed but not caught. Suspect wet soil packed under pans.

^b Day of heavy fog, prevented view of traps, pulled sets early.

^c Suspect missed capture of immature, traps pulled away from set, eagle seen flying low away from area.

^d Fed at sets during 2 other trap attempts without being captured. Suspect wet soil packed under pans.

^e Fed for 11 mins., flushed by coyote and later returned to set and was captured.

^f Fed for a few mins. previous day, flushed by subadult. Caught next day when attempting to fly from approaching subadult.

^g Coyotes stole rabbits from set. Later used camouflaged 2-way radios to frighten away coyotes and ravens.

Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas, 1992

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ANNUAL SUMMARY

We conducted 2,260 point counts of raptors and ravens in the Integrated Study Area (ISA) between 22 April 1991 and 15 July 1992. Mean counts were highest in the 1991 breeding season (4.10 birds/count), slightly lower in the 1991-92 winter season (3.23 birds/count) and 1992 breeding season (3.22 birds/count), and lowest in the 1991 dry season (1.85 birds/count). Counts at OTA sites were lower than at non-OTA sites in 3 of 4 seasons (dry 1991, winter 1991-2, and breeding 1992), though for raptors this difference was only significant in the 1991 dry season. Raptors and ravens exhibited different patterns of daily abundance inside and outside the OTA in the 1991 dry season, but in all other seasons diurnal patterns were not linked to site location with respect to the OTA. During simultaneous observations conducted at paired OTA and non-OTA sites, raptors and ravens were present outside the OTA more often than inside in the presence of military training during the breeding seasons; no difference was found for non-breeding seasons. We classified our sites as being dominated by sagebrush (*Artemisia tridentata*), by shadscale (*Atriplex confertifolia*), or by grasses and exotic annuals. Raptor counts were highest at sagebrush sites in every season except dry 1991; raven counts were highest at sagebrush sites only in the 1991 breeding season. Military training did not affect habitat use in any season. On non-OTA sites with agriculture within 2 km of the site center point, raptor numbers were significantly higher than at sites with no agriculture in the 1991 dry season; raven counts were higher at sites near agriculture in every season except breeding 1991. When sites near agriculture were omitted from the analysis, some differences between OTA and non-OTA counts were reduced.

OBJECTIVES

1. To compare raptor detection rates inside and outside the OTA during different seasons, during different diurnal periods, and during periods of military training and periods of no training.

2. To assess differences in habitat use by raptors and ravens during different seasons, during different diurnal periods, and during periods of military training and periods of no training.

■ INTRODUCTION

Study 1 is part of a long-term investigation into the effects of military training on birds of prey and their prey populations in the Snake River Birds of Prey Area (SRBOPA). Designed as an extensive survey of raptor distribution, behavior, and response to military activity, Study 1 is comprised of a series of point counts conducted during different temporal and military-related conditions.

The overall objective of this study is to provide information about the probability that a given tract of land in the SRBOPA will be used by a certain species of raptor under a given set of conditions (season, time of day, presence/absence of military activity). This information will allow managers to schedule military training for time periods and locations that will have minimal impacts on birds of prey and allow them to prioritize areas for habitat protection and/or restoration. While the immediate goal of the study is to assess the impact of military training on raptor distribution and behavior, the data collected herein will provide a base of information on the relative abundance of raptor species in the SRBOPA for use in long-term monitoring.

Study 1 is a year-round project with 3 field seasons a year: breeding (1 March - 15 July), dry (16 July - 31 October), and winter

(1 November - 28/29 February). This report includes preliminary analysis of data collected in 1991 and 1992 (breeding 1991, dry 1991, winter 1991-92, and breeding 1992).

■ METHODS

Observations

We used 190 point count sites situated throughout the Integrated Study Area (ISA) north of the canyon rim; 70 sites are located within the OTA, and 120 sites are outside the OTA. Site selection and pairing methods are described in the 1991 Annual Report (Strickler and Watson 1991). Each site is comprised of a circle with a 1000-m radius. Point counts were conducted in the same manner as in 1991, with each count consisting of a 20-min period of looking for all raptors and ravens within 1000 m of the center point. We alternated intensive scans of 90 degree quadrants of the horizon through 10 x 40 binoculars with brief 360-degree naked eye scans. Every bird that was seen within 1000 m was observed for 60 sec, and the following data were recorded: species (if identifiable), time at which the bird was first seen, habitat over which the bird was flying, behavior over the 60-sec focal sample, and any appropriate comments.

In addition, we collected the following weather data at each count: temperature, wind speed, wind direction, and sky cover. Hourly barometric pressure information was obtained for each count day from the daily summary of weather at the Boise Air Terminal produced by the National Weather Service.

Raptor detections (OTA vs. off-OTA)

Time of day

Data collection -- We censused each site during each of 3 diurnal periods (morning, afternoon, and evening) during each season. The length of each diurnal period was a function of the length of photoperiod and consequently varied throughout the year.

Analysis -- Because of the lack of independence of counts caused by multiple counts at each site, our study design must be considered a repeated measures design, with diurnal period the main repeated factor. However, because of the nonnormal nature of our data, traditional repeated measures analyses of variance are not applicable. Permutation procedures, which are distribution-free and allow for repeated measures analysis, have recently been developed and shown to be a powerful, viable replacement for many standard parametric tests (Slauson 1988; Biondini et al. 1988; Cade and Hoffman 1990; Mielke 1991; Cade, U.S.F.W.S., pers. commun.).

Traditional parametric methods assume that the underlying distribution model for a population is normal (with equal variance or an equal variance-covariance matrix) and linear. In practice, these assumptions may be very difficult to meet with ecological data (Biondini 1988). Additionally, the methods used to calculate the pertinent parametric statistics involve least squares; as a result, the analysis space is inherently non-metric. If the space occupied by the data is not also non-metric, the congruence principle is violated. The data space of most ecological studies is usually perceived to be Euclidean, the most common metric space (Mielke 1986). Permutation procedures are free from

assumptions about normal distribution, equality of variances, or linearity, and use Euclidean distances in the analysis space, thereby satisfying the congruence principle (Biondini 1988). We used multi-response permutation procedures (MRPP; Slauson et al. 1991) throughout our tests of repeated measures models of raptor detection rates.

We ran separate analyses on breeding 1991, dry 1991, winter 1991-92, and breeding 1992 samples. Sites with fewer than 3 counts in a single season were excluded from the analysis for that season. For the overall interaction between OTA (on = 1; off = 2) and diurnal period (morning = 1; afternoon = 2; evening = 3) we examined the multivariate tests in MRPP for interaction between the group effect (OTA) and the repeated measures effect (period) using linear contrast variables between the repeated measures (morning-afternoon, morning-evening, afternoon-evening). A significant interaction between OTA and period indicates that the time of day of the count influences the difference between numbers of birds detected inside the OTA and numbers detected outside the OTA, and subsequent tests for the subeffects of group and trial must be performed separately within levels of OTA and period. If no significant interaction is found univariate tests can be made of the main group effect by averaging the repeated measures into 1 value and comparing it to the 2 group levels (OTA = 1 and OTA = 2); the main effect of time is tested by a series of pairwise comparisons for the 3 levels of period (Looney and Stanley 1989). Tests for subeffects were adjusted for multiple comparisons using the Bonferroni method by dividing the critical P-values by the number of univariate tests (Harris 1985).

Throughout our analyses, we ran separate tests on 3 groups of birds: raptors and ravens combined (hereafter referred to as "all birds" or "total"); raptors; and ravens. Analyses on individual species will be conducted later when more data are available for each species.

Military training

Data collection -- Military activity data were gathered from a variety of sources. First, we recorded any training activity heard or seen during or immediately before or after a count. The time of activity and, if possible, the type and location of the activity were recorded. The limitations of such field observations are twofold: a) actual type and location of training are difficult to assess, especially for artillery, which may be heard but not seen; and b) some types of training such as maneuvers and bivouacs could take place close to the count site without being heard or seen by the observer if, for example, the activity were on the opposite side of a butte or hill from the count site.

Two additional sources of military activity data were provided by the Idaho Army National Guard (IDARNG). The Range Management Input Worksheets provided general information on the daily activity of a particular military unit, including number of personnel, number and type of vehicles and aircraft, and amount and type of ammunition. These worksheets indicated that a certain number of people and equipment were present in a very general training area (usually 1 of 10 sectors into which the 53,015-ha OTA is divided) during a 24-hr period, but gave no specific time, duration, or location of actual movement or other activity. The other IDARNG

document we used was the Cinder Cone log book. A record of all communications with the range control center, the Cinder Cone log was primarily useful for determining when a range had been approved for firing. The "firing" designation, however, does not indicate whether or when firing actually occurred.

Because of the shortcomings of the available military activity data, it was not appropriate or even possible to assign rigorous designations of "military training" or "no military training" to each point count based on the site's proximity to a particular type of military activity during a specific time period. The most reliable data available to us, our own observations of activity before, during, or after a count, were inherently untrustworthy because we could not be sure that simply because we had not seen any military training, none had taken place.

Therefore, we decided to apply a "3 km - 3 hr" rule to training. If military activity of any sort occurred within 3 km and up to 3 hr before a count was conducted at a site in the OTA, that count was considered to have taken place during a period of military training; counts conducted when no known training took place within 3 km and 3 hr were said to have been in a period of no training. This classification of military activity, which we used in our analyses as a categorical variable (presence = 1; absence = 0), is clearly a conservative estimation and does not respond to possible real differences in the impacts of various types, times, and locations of training.

We compared raptor activity during periods of military training and periods of no training only on paired sites because of the

impracticability of assigning "training" or "no training" labels to unpaired off-OTA points.

Analysis -- Repeated measures analysis was not possible for testing the influence of military activity on raptor detection rates inside and outside the OTA because the military activity label at each OTA site was not constant across all counts. Using only the paired counts, contingency tables were formed with categorical estimates of military activity and presence or absence of birds at OTA and off-OTA sites. Each pair of counts was scored according to whether raptors were detected at the off-OTA member of the pair but not at the OTA site (presence/absence = 1) or raptors were seen at the OTA site but not at the off-OTA site (presence/absence = 2). Because this scoring eliminated like pairs of counts (birds present at both sites or absent at both sites) our dataset was considerably reduced. To avoid questionable results owing to sparse cells in the tables, we combined seasons into 2 groups: breeding (breeding 1991 and breeding 1992) and nonbreeding (dry 1991 and winter 1991-92). We performed separate analyses on each group. We tested the null hypothesis that military training does not influence use of the OTA by raptors and ravens using the Tables module in SYSTAT (Wilkinson 1990).

Raptor detections and habitat

Habitat analysis used the point count and military activity data described above.

Habitat classification

During the site selection and pairing process (Strickler and Watson 1991), we described each point count site with ocular estimates

of the percent cover of vegetation types (i.e. *Artemisia tridentata*, *Chrysothamnus* spp., *Ceratoides lanata*, *Atriplex confertifolia*, *Artemisia*-dominated shrub mosaic, *Atriplex*-dominated shrub mosaic, grass/exotic annual, and agriculture). We feel that comprehensive habitat analysis would best be performed with more precise data than those we have collected so far, and should therefore be postponed either until the BLM's GIS can provide us with accurate proportions of habitat classes for our sites or until we have collected more detailed vegetation data for our sites. Thus at this time our habitat analyses use only grouped classifications; we have classified each site as "shrub," in which the percent cover of all shrub species is 15% or greater, or "grass/exotic annual," for sites with less than 15% shrub cover. The "shrub" class is further broken down into 2 categories: sagebrush-associated shrub (including *Artemisia tridentata*, *Chrysothamnus* spp., *Ceratoides lanata*, or a mosaic of 2 or more species; habitat = 1), shadscale-associated shrub (including *Atriplex confertifolia*, *Grayia spinosa*, *Artemisia spinescens*, or a mosaic of 2 or more species; habitat = 2). The grass/exotic annual class (habitat = 3) includes perennial native grasses, nonnative annual grasses such as *Bromus tectorum*, nongrass exotic annuals such as *Salsola iberica*, and fallow agriculture. Sites with greater than 25% productive agriculture were omitted from habitat analyses.

Using more finely divided habitat groupings such as those suggested by Knick et al. (1991) to assign a single class to a particular site is generally not possible because of the large scale at which our sites are sampled (314 ha per site).

Time of day

Analysis -- The interaction between habitat class and the repeated effect of diurnal period was tested with a multivariate, repeated measures permutation procedure (Slauson et al. 1991). Applicable univariate tests for main effects and subeffects were run depending upon the significance of the 2-way interaction, with Bonferroni adjustments for multiple comparisons, where appropriate, applied as described above. We ran separate analyses on each season, and on each major group of birds.

Military training

Analysis -- The impact of military training on habitat use by raptors and ravens in the ISA was tested using a multi-response permutation procedure with 2 factors: habitat and military training. We analyzed breeding (breeding 1991 and breeding 1992) and non-breeding (dry 1991 and winter 1991-92) seasons separately for total birds, raptors, and ravens.

Agricultural lands

To evaluate the effect of private agricultural lands outside the OTA on our counts, we classified all non-OTA sites as "near agriculture" ("ag") if there was irrigated and/or cultivated land (pasture or intensely managed) within 2 km of the center point of the site and "no agriculture" ("non-ag") if there was no agriculture within 2 km of the center point.

We compared mean counts at ag sites and non-ag sites using MRPP to perform univariate permutation tests. To assess the influence of agricultural lands on the OTA/off-OTA comparisons, we omitted all "near agriculture" sites and ran the

multivariate repeated measures permutation procedures described above, testing for the interaction of OTA and diurnal period. Different results between this test and the test in which agricultural lands were included would indicate that ag lands have a strong effect on the distribution of raptors and ravens in the ISA.

RESULTS

Raptor detections (OTA v. non-OTA)

We conducted 2,260 point counts between 22 April 1991 and 15 July 1992, 832 at OTA sites and 1,428 at off-OTA sites. Sixty-nine percent (4,861) of the 7,000 birds detected at these counts were common ravens. Fourteen species of raptors were recorded (listed in order of frequency of occurrence): Northern harrier (*Circus cyaneus*); prairie falcon (*Falco mexicanus*); golden eagle (*Aquila chrysaetos*); red-tailed hawk (*Buteo jamaicensis*); rough-legged hawk (*Buteo lagopus*); Swainson's hawk (*Buteo swainsonii*); ferruginous hawk (*Buteo regalis*); American kestrel (*Falco sparverius*); short-eared owl (*Asio flammeus*); turkey vulture (*Cathartes aura*); bald eagle (*Haliaeetus leucocephalus*); burrowing owl (*Speotyto cunicularia*); Cooper's hawk (*Accipiter cooperii*); sharp-shinned hawk (*Accipiter striatus*).

The average of all birds per count over 4 seasons was 3.10; raptors averaged 0.95 birds per count, and the average raven count was 2.15. Average total counts were highest in the 1991 breeding season (4.10 birds per count) and lowest in the 1991 dry season (1.85 birds per count), with counts in the winter 1991-92 and breeding 1992 seasons each averaging about 3.23 birds per count (Table 1). Raptors and ravens followed similar patterns through the year (Fig. 1).

Table 1. Total, mean, standard deviation, and percent zero counts of point counts of raptors and ravens conducted during 4 consecutive seasons in 1991 and 1992 in the ISA. *N* = number of counts.

	Breeding 1991 <i>N</i> =559	Dry 1991 <i>N</i> =567	Winter 1991-92 <i>N</i> =564	Breeding 1992 <i>N</i> =570
<u>All birds</u>				
Total	2291	1047	1827	1835
mean	4.10	1.85	3.24	3.22
SD	4.60	5.68	6.33	5.03
% zero counts	15	54	25	29
<u>Raptors</u>				
Total	816	254	484	585
mean	1.46	0.45	0.86	1.03
SD	1.65	1.46	1.12	1.36
% zero counts	34	72	51	49
<u>Ravens</u>				
Total	1475	793	1343	1250
mean	2.64	1.40	2.38	2.19
SD	4.17	5.21	6.01	4.62
% zero counts	34	70	45	46

Counts in the breeding season, the only season for which we have more than 1 set of data, differed between the 2 years. In the 1991 breeding season, non-OTA mean counts of raptors decreased gradually through the season. The OTA raptor counts dropped sharply between mid- and late season cycles of counts (Fig. 2a); however, this difference was not significant. Most of the seasonal decrease in breeding 1992, on the other hand, took place between the first and second cycles (early and mid-season). The slope of the decrease was gentler after mid-season. In both seasons, OTA counts showed a greater decrease than did non-OTA counts, although the difference between rates

of decrease inside and outside the OTA was only significant in 1992 (1991: $d = 2.14$, $P = 0.14$; 1992: $d = 6.16$, $P < 0.001$). Raven detections increased through the 1991 breeding season but decreased across the study area in breeding 1992, with 1992 OTA raven counts showing the largest drop (Fig. 2b). Frequency of zero counts (counts at which no birds were detected) rose gradually through the 1991 breeding season, peaking in the 1991 dry season, but increased sharply after mid-season in 1992; OTA zero counts peaked in mid-breeding season in 1992 whereas non-OTA zero counts followed a pattern closer to that of 1991 (Fig. 3).

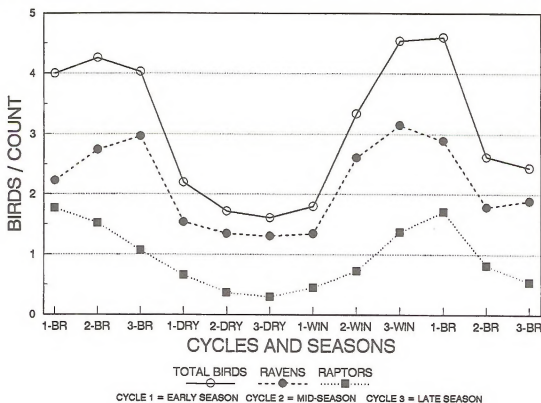


Fig. 1. Mean counts of raptors, ravens, and total birds over 4 consecutive seasons in 1991 and 1992 in the ISA.

Time of day

Breeding season 1991 (Table 2, Fig. 4a) -- We found no significant interaction between OTA and period for all birds ($d = 1.93$, $P = 0.058$), indicating that abundance of birds through the day did not differ relative to the OTA. There were no significant differences between OTA and non-OTA counts or between different times of day ($P > 0.10$).

Changes in raptor counts through the day were similar between OTA and off-OTA sites ($d = 1.94$, $P = 0.49$). Counts conducted in the evening were significantly higher than

morning counts ($d = 2.96$, $P = 0.017$) and afternoon counts ($d = 2.77$, $P = 0.005$).

The OTA*period interaction was significant for ravens ($d = 1.94$, $P = 0.031$), but there was no significant OTA effect within diurnal periods ($P > 0.05$). Among OTA counts, ravens were seen more in the morning than in the afternoon ($d = 4.99$, $P = 0.0016$).

Dry season 1991 (Table 3, Fig. 4b) -- There was a strong OTA*period effect for all birds in the dry season ($d = 1.97$, $P < 0.001$). Counts were higher outside the OTA than inside in every time period: averaging 2.47

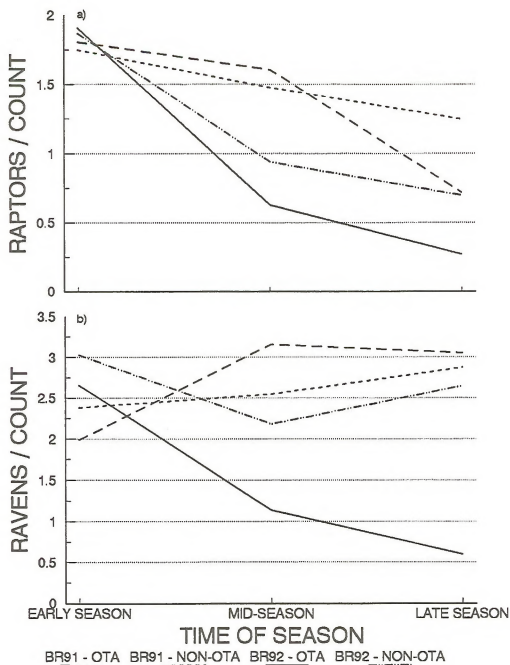


Fig. 2. Comparison of mean counts for raptors (a) and ravens (b) inside and outside the OTA in the ISA.

Table 2. Mean counts of raptors and ravens at OTA and non-OTA sites in the ISA during morning, afternoon, and evening diurnal periods in the 1991 breeding season (22 April 1991 - 15 July 1991).

	ALL BIRDS		RAPTORS		RAVENS	
	OTA	Non-OTA	OTA	Non-OTA	OTA	Non-OTA
<u>Morning</u>						
N	70	120	70	120	70	120
mean	4.53	4.31	1.20	1.41	3.33	2.90
SD	4.79	4.64	1.71	1.31	4.55	4.44
<u>Afternoon</u>						
N	69	120	69	120	69	120
mean	3.06	4.11	1.15	1.33	1.91	2.78
SD	3.39	4.71	1.12	1.47	2.91	4.35
<u>Evening</u>						
N	65	115	65	115	65	115
mean	4.77	3.85	1.88	1.77	2.89	2.09
SD	6.19	3.84	2.38	1.82	5.43	3.09

birds per count outside the OTA compared with 1.10 birds per count inside in the morning ($d = 2.87$, $P < 0.001$); 2.08 birds per count outside the OTA and 0.33 birds per count inside in the afternoon ($d = 2.22$, $P < 0.001$); and 3.04 birds per count outside the OTA and 0.55 birds per count inside in the evening ($d = 3.65$, $P < 0.001$). Within the OTA, total detections dropped off in the afternoon ($d = 3.40$, $P = 0.003$); outside the OTA raven counts were lower in the afternoon while raptor counts remained steady over all diurnal periods, but neither difference was significant.

Raptors ($d = 2.01$, $P = 0.01$) and ravens ($d = 1.98$, $P < 0.001$) followed the same trend, with significantly different daily patterns of occurrence between the OTA and off-OTA. Both raptor and raven counts were higher off the OTA in all diurnal periods ($P < 0.01$ in all cases). Although we found

similar numbers of detections in all times of day outside the OTA, afternoon counts at OTA sites were lower than morning counts (raptors: $d = 2.51$, $P = 0.004$; ravens: $d = 4.5$, $P = 0.005$).

Winter season 1991-92 (Table 4, Fig. 4c) -- There were no differences in daily variation between the OTA and non-OTA for any group of birds (OTA*period interaction $P > 0.07$ in all cases). The main OTA effect of lower counts in the OTA was significant for all birds ($d = 2.73$, $P = 0.024$) and for ravens ($d = 2.38$, $P = 0.016$), but not for raptors ($d = 0.73$, $P = 0.55$). Total counts and raven counts were higher in the evening than in the morning (all birds: $d = 6.66$, $P = 0.01$; ravens: $d = 6.54$, $P = 0.003$); evening counts were also higher than afternoon counts (all birds: $d = 7.20$, $P < 0.001$; ravens: $d = 7.36$, $P = 0.001$). Among raptors the afternoon/evening

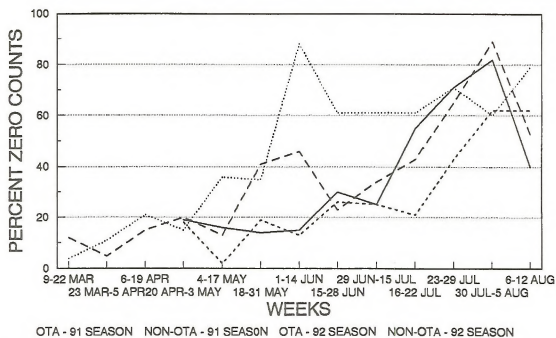


Fig. 3. Comparison of 2-week periods in March-August 1991 and 1992 for percent of counts at which no raptors or ravens were detected (zero counts) in the ISA. Counts at OTA and non-OTA sites in each year are shown separately.

Table 3. Mean counts of raptors and ravens at OTA and non-OTA sites in the ISA during morning, afternoon, and evening diurnal periods in the 1991 dry season (16 July 1991 - 31 October 1991).

	ALL BIRDS		RAPTORS		RAVENS	
	OTA	Non-OTA	OTA	Non-OTA	OTA	Non-OTA
<u>Morning</u>						
N	70	120	70	120	70	120
mean	1.10	2.47	0.27	0.81	0.83	1.66
SD	3.69	5.24	0.59	2.80	3.70	3.09
<u>Afternoon</u>						
N	69	119	69	119	69	119
mean	0.33	2.08	0.22	0.54	0.12	1.55
SD	0.72	4.24	0.62	0.96	0.40	4.01
<u>Evening</u>						
N	69	120	69	120	69	120
mean	0.55	3.04	0.16	0.40	0.39	2.64
SD	1.46	9.70	0.56	0.74	1.33	9.54

Table 4. Mean counts of raptors and ravens at OTA and non-OTA sites in the ISA during morning, afternoon, and evening diurnal periods in the 1991 winter season (1 November 1991 - 29 February 1992).

	ALL BIRDS		RAPTORS		RAVENS	
	OTA	Non-OTA	OTA	Non-OTA	OTA	Non-OTA
<u>Morning</u>						
N	70	119	70	119	70	119
mean	2.01	3.08	0.59	0.92	1.43	2.15
SD	2.48	3.23	0.91	1.14	2.20	2.87
<u>Afternoon</u>						
N	70	116	70	116	70	116
mean	1.61	2.72	0.60	0.82	1.01	1.90
SD	1.76	4.72	0.84	1.13	1.40	4.27
<u>Evening</u>						
N	70	119	70	119	70	119
mean	3.76	5.29	1.14	0.98	2.61	4.31
SD	7.58	10.62	1.33	1.16	7.51	10.18

difference was significant ($d = 1.97$, $P = 0.005$), but counts were lower in the afternoon.

Breeding season 1992 (Table 5, Fig. 4d) -- The OTA*period interaction showed no sign of differences in daily timing of abundance between the OTA and non-OTA for any group of birds ($P > 0.10$ in all cases). Across all time periods OTA counts were again significantly lower than off-OTA counts for all birds ($d = 2.80$, $P = 0.001$) and for ravens ($d = 2.33$, $P = 0.002$). For all groups of birds, numbers of detections decreased through the day; evening counts were significantly lower than morning counts (all birds: $d = 7.19$, $P < 0.001$; raptors: $d = 2.41$, $P = 0.002$; ravens: $d = 6.61$, $P < 0.001$).

Military training

Of 190 pairs of counts that were conducted in the non-breeding seasons combined (dry 1991 and winter 1991-92), counts took place in the presence of military training at the OTA member of 22 pairs. The null hypothesis that military activity does not affect raptor and raven use of the OTA could not be rejected for any group of birds (Fig. 5; all birds: $G_1 = 0.71$, $P = 0.68$; raptors: $G_1 = 0.07$, $P = 0.80$; ravens: $G_1 = 0.02$, $P = 0.89$).

During the 1991 and 1992 breeding seasons combined, 33 out of 187 pairs of counts occurred when military activity was recorded at the OTA member of the pair. Birds were present more often at non-OTA sites than at

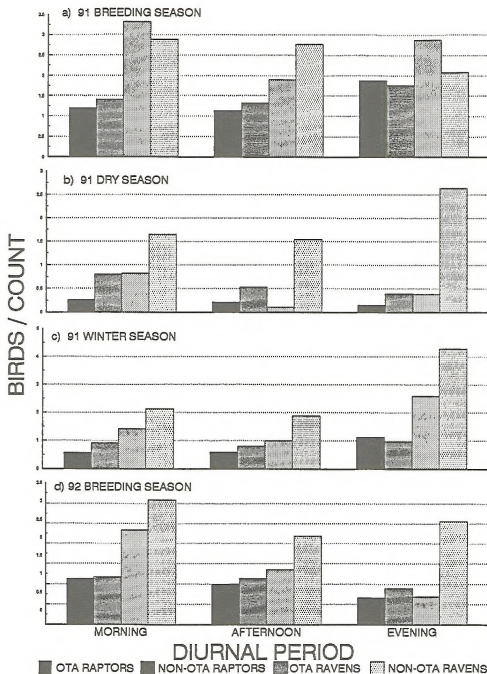


Fig. 4. Comparisons of mean counts of raptors and ravens in the ISA in different diurnal periods, inside and outside the OTA, for 91 breeding (a) 91 dry (b) 91-92 winter (c) and 92 breeding (d) seasons.

OTA sites when military training was present, although this difference was only significant for raptors and ravens combined (all birds: $G_1 = 6.81$, $P = 0.009$; raptors: $G_1 = 1.32$, $P = 0.25$; ravens: $G_1 = 3.49$, $P = 0.06$).

Raptor detections and habitat

Eighty-four sites were classified as *Artemisia*-associated shrub, 20 as *Atriplex*-associated shrub, and 71 as grass/exotic annual.

Time of day

Breeding season 1991 -- No interaction was found between habitat class and time of day, indicating that raptors and ravens do not adjust their use of different habitat types depending on the time of day ($P > 0.39$ for all groups of birds). Both raptors and ravens, however, exhibited significant differences in habitat use regardless of diurnal period (all birds: $d = 3.28$,

$P = 0.00005$; raptors: $d = 1.13$, $P = 0.003$; ravens: $d = 2.66$, $P < 0.001$). In all cases, mean counts were highest at sagebrush-associated shrub sites and lowest at shadscale-associated shrub sites (Table 6).

Dry season 1991 -- Mean counts of raptors and ravens were similar in all habitat classes across all diurnal periods ($P > 0.07$ in all cases).

Winter season 1991-2 -- Time of day did not affect habitat use ($P > 0.64$ for all groups of birds). Raptors were detected significantly more often at sagebrush sites than in the other 2 habitat classes ($d = 0.66$, $P = 0.006$).

Breeding season 1992 -- Raptors and ravens did not use different habitat types depending on the time of day ($P > 0.77$ for all groups of birds). Total counts ($d = 2.58$, $P < 0.001$), raptor counts ($d = 0.67$, $P < 0.001$) and raven counts ($d = 2.24$, $P = 0.03$) were higher at sagebrush sites than at shadscale or grass/exotic annual sites.

Table 5. Mean counts of raptors and ravens at OTA and non-OTA sites in the ISA during morning, afternoon, and evening periods in the 1992 breeding season (1 March 1992 - 15 July 1992).

	ALL BIRDS		RAPTORS		RAVENS	
	OTA	Non-OTA	OTA	Non-OTA	OTA	Non-OTA
<u>Morning</u>						
N	70	120	70	120	70	120
mean	3.49	4.28	1.14	1.18	2.34	3.09
SD	3.69	6.33	1.25	1.35	3.02	5.90
<u>Afternoon</u>						
N	70	120	70	120	70	120
mean	2.36	3.33	1.00	1.14	1.36	2.19
SD	2.70	3.90	1.31	1.52	1.99	3.54
<u>Evening</u>						
N	70	120	70	120	70	120
mean	1.37	3.48	0.67	0.91	0.70	2.57
SD	2.02	6.89	1.22	1.35	1.20	6.59

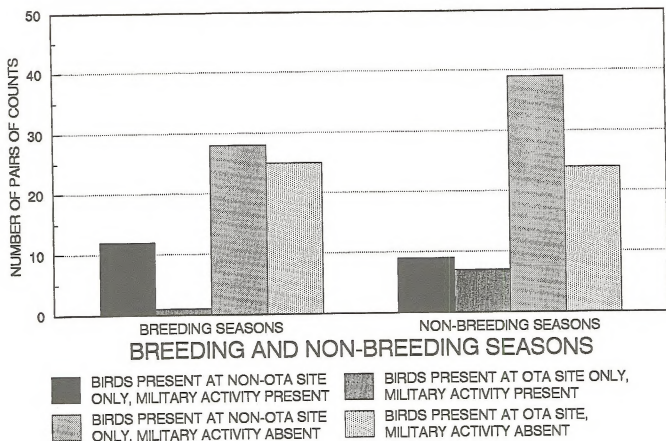


Fig. 5. Occurrence of raptors and ravens at OTA and non-OTA sites during simultaneous counts of paired sites in the ISA in 1991 and 1992, in the presence or absence of military training.

Table 6. Mean counts of raptors and ravens in different habitat classes in the ISA during 4 consecutive seasons in 1991 and 1992.

	Breeding 1991	Dry 1991	Winter 1991-92	Breeding 1992
<u>All Birds</u>				
<i>Sagebrush</i>				
N	252	251	248	252
mean	4.95	1.14	3.78	3.50
SD	5.03	2.37	8.11	4.86
<i>Shadscale</i>				
N	60	60	60	60
mean	2.53	0.90	1.75	1.62
SD	2.21	1.39	1.77	2.11
<i>Grass</i>				
N	202	211	212	213
mean	3.17	1.56	2.43	2.84
SD	3.94	4.32	3.81	5.65
<u>Raptors</u>				
<i>Sagebrush</i>				
N	252	251	248	252
mean	1.68	0.36	0.95	1.25
SD	1.75	0.71	1.13	1.41
<i>Shadscale</i>				
N	60	60	60	60
mean	0.93	0.25	0.48	0.67
SD	1.09	0.57	0.81	0.93
<i>Grass</i>				
N	202	211	212	213
mean	1.31	0.40	0.72	0.68
SD	1.68	0.82	1.06	1.02
<u>Ravens</u>				
<i>Sagebrush</i>				
N	252	251	248	252
mean	3.27	0.79	2.83	2.25
SD	4.62	2.13	7.80	4.38
<i>Shadscale</i>				
N	60	60	60	60
mean	1.60	0.65	1.27	0.95
SD	1.86	1.34	1.54	1.61
<i>Grass</i>				
N	202	211	212	213
mean	1.87	1.16	1.71	2.16
SD	3.45	4.15	3.52	5.35

Military training

The null hypothesis that presence or absence of military training does not affect habitat use by raptors and ravens could not be rejected for any group of birds in any season ($P > 0.05$ for all cases).

Agricultural lands

Of 120 non-OTA point count sites, 48 had active agriculture within 2 km of the center point (Table 7). In the 1991 breeding season, raptor and raven detections were not

different between non-OTA sites that were near agriculture and sites with no agriculture ($P > 0.12$ for all groups). In the 1991 dry season, we found a very strong difference for all groups of birds (all birds: $d = 3.00$, $P < 0.001$; raptors: $d = 0.67$, $P < 0.001$; ravens: $d = 2.63$, $P < 0.001$). Mean counts at ag sites were 3 times higher than those at non-ag sites. Raptor counts in winter 1991-92 and in breeding 1992 were similar between sites (winter: $d = 0.77$, $P = 0.07$; breeding: $d = 0.86$, $P = 0.07$) but raven counts were higher at agricultural sites (winter: $d = 2.72$, $P = 0.04$; breeding: $d = 2.32$, $P < 0.001$).

Table 7. Mean counts of raptors and ravens at non-OTA sites in the ISA, comparing sites within 2 km of agriculture with sites with no nearby agriculture, during 4 consecutive seasons in 1991 and 1992.

	Breeding 1991	Dry 1991	Winter 1991-92	Breeding 1992
All Birds				
<i>Near Agriculture</i>				
N	48	48	44	48
mean	4.61	4.69	4.27	4.63
SD	3.72	6.28	4.01	4.55
<i>No Agriculture</i>				
N	67	71	70	72
mean	3.70	1.09	2.71	3.07
SD	3.01	1.35	2.52	2.77
Raptors				
<i>Near Agriculture</i>				
N	48	48	44	48
mean	1.67	0.94	1.04	1.28
SD	1.20	1.50	0.84	1.16
<i>No Agriculture</i>				
N	67	71	70	72
mean	1.34	0.35	0.76	0.94
SD	0.93	0.43	0.65	0.69
Ravens				
<i>Near Agriculture</i>				
N	48	48	44	48
mean	2.94	3.76	3.24	3.35
SD	3.42	5.96	3.69	4.19
<i>No Agriculture</i>				
N	67	71	70	72
mean	2.36	0.74	1.95	2.13
SD	2.49	1.10	2.36	2.57

When non-OTA sites near agriculture were excluded from the analysis, the repeated measures permutation procedure used above for OTA*period effect no longer found any significant interaction between OTA and time of day ($P > 0.17$ in all cases). In addition, mean counts at OTA and non-OTA sites were more similar when agricultural sites were omitted (Table 8); only in dry season 1991 were counts at OTA sites still significantly lower (all birds: $d = 1.10$, $P = 0.006$; raptors: $d = 0.38$, $P = 0.04$; ravens: $d = 0.88$, $P = 0.01$).

■ DISCUSSION

With only 4 seasons of data it is premature to discuss definite trends in numbers of detections, but the cycling we found in raptor and raven counts through the year is what one would expect: the highest counts in the breeding season, when birds are most active; a sharp drop in numbers when the young birds have dispersed and the main prey species, Townsend's ground squirrel (*Spermophilus townsendii*), has immersed; and an increase in detections as winter residents move into the SRBOPA. Higher counts continue or increase as the breeding season begins again, despite winter inhabitants leaving the area, as summer residents return and begin to nest.

Our season designations were set to approximate the seasonal patterns in raptor phenology and numbers. However, both climatic conditions and phenology can vary significantly within a shorter time frame and so our seasonal approach to analyses may not detect real responses of the birds to fluctuations in seasonal weather conditions. In 1991, for example, southern Idaho's spring was cool and wet following an

unusually cold winter, and breeding season counts peaked mid-season. Breeding season 1992 counts, on the other hand, began dropping early in the season after a mild winter and a spring that was warmer and dryer than normal (Fig. 6; Fig. 2). Townsend's ground squirrels were active earlier in the spring in 1992 than in 1991 (Schooley, pers. commun.); our counts, which in 1992 peaked at the beginning of the breeding season (Fig. 1), may have reflected a shift in the breeding cycle of raptors and ravens corresponding to the change in available prey. It will be interesting to examine data from Studies 2 and 3 regarding timing and success of nesting attempts to see whether unusual rates of nesting failure or dispersal can be tied to the different patterns of abundance we found in our breeding season data. Continued monitoring of point count data may show which pattern of annual cycle, if any, is typical.

Military activity also has a seasonal component that is not necessarily reflected in our classification of military training presence or absence. Most intensive training takes place from May-August, corresponding to most of our breeding season and the first month of the dry season. During this period, training includes widespread and intensive activities such as tank maneuvers, bivouacs, long periods of artillery firing, and helicopter maneuvers; large numbers of personnel and vehicles are involved. Training activities in the rest of the year usually involve far fewer people and vehicles and are typically limited to maintenance and low-level training. It is thus not surprising that we found a significant impact of military training on numbers of raptor detections only in the breeding seasons, for it was only in these seasons that intense training occurred. Our

Table 8. Mean counts of raptors and ravens at all sites in the ISA at which active agriculture is less than 25%, conducted during 4 consecutive seasons in 1991 and 1992.

	Breeding 1991	Dry 1991	Winter 1991-92	Breeding 1992
<u>All Birds</u>				
<u>OTA</u>				
N	64	68	70	70
mean	4.17	0.67	2.46	2.41
SD	3.88	1.46	2.82	1.46
<u>Non-OTA</u>				
N	67	71	70	72
mean	3.70	1.09	2.71	3.07
SD	3.01	1.35	2.52	2.77
<u>Raptors</u>				
<u>OTA</u>				
N	64	68	70	70
mean	1.41	0.22	0.78	0.94
SD	1.16	0.34	0.58	0.65
<u>Non-OTA</u>				
N	67	71	70	72
mean	1.34	0.35	0.76	0.94
SD	0.93	0.43	0.65	0.69
<u>Ravens</u>				
<u>OTA</u>				
N	64	68	70	70
mean	2.76	0.46	1.69	1.47
SD	3.23	1.30	2.72	1.18
<u>Non-OTA</u>				
N	67	71	70	72
mean	2.36	0.74	1.95	2.13
SD	2.49	1.10	2.36	2.57

treatment of military training overlooks differences in seasonal intensity and in the varying impacts of the different types of military activity (bivouacs, wheeled vehicles, tanks, explosions, air traffic, etc.). Given the limitations of the data available, however, it seems the only treatment possible.

Military activity in 1992 was marked by a period of heavy training, from 28 May - 20 June, known as "Operation Bold Shift."

During this period up to 4,000 troops, 100 tanks, and hundreds of wheeled vehicles were present in the OTA. The number of OTA counts at which we detected no birds at all increased dramatically in the 2-week period corresponding to the start of Operation Bold Shift. This may have been a direct result of the heavy use of the OTA; however, since non-OTA zero counts were also higher in the same period, the change in zero counts may have been a result of the

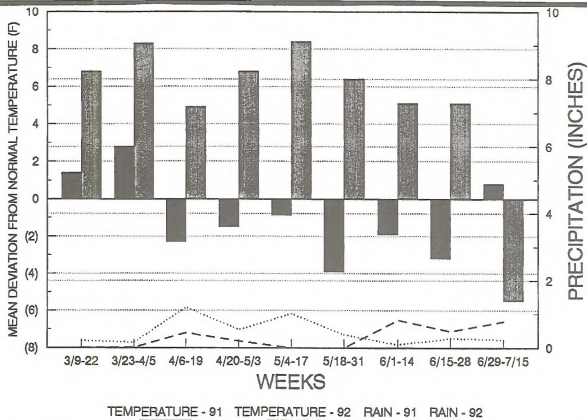


Fig. 6. Trends in temperature deviation from normal and precipitation at Boise Air Terminal in the 1991 and 1992 breeding seasons. Weather data source: National Weather Service, Boise, Idaho.

relatively early seasonal shifts in phenology, i.e. early senescence of grasses, hibernation of ground squirrels, and dispersal of non-breeding or unsuccessful pairs of birds.

Agricultural lands appear to have a strong influence on the distribution of birds in the ISA. Judging by the magnitude of the difference in use between ag and non-ag sites, it is probable that birds prefer non-OTA ag lands, especially after native vegetation elsewhere has become senescent. This may indicate raptor and raven movement out of the OTA into non-OTA cultivated lands after the growing season and

would affect our OTA/non-OTA comparison, confounding the effect of military training (which is presumed to be the major difference between OTA and non-OTA land). The repeated measures analysis in which ag sites are excluded supports this by showing a reduced OTA effect. Even without ag sites, however, the 1991 dry season OTA counts were significantly lower than non-OTA counts, indicating that agricultural land is not the only factor causing an OTA/non-OTA difference. In future analyses, the confounding factor of agricultural lands will be examined more closely.

■ PLANS FOR NEXT YEAR

Point counts will continue as in 1991 and 1992. No major changes in methods are planned. Integrating our results with those of other studies will be an increasing focus in the coming year, as will extended analyses comparing seasons from different years as our dataset grows. We will be looking at ways to incorporate weather variables as covariates into our analyses. Statistical methods for analyzing habitat use versus availability within each site and over the whole ISA will also be investigated, as will optimal analyses for our raptor behavioral data.

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Habitat Relationships of Townsend's Ground Squirrels

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ANNUAL SUMMARY

*During our second field season, January through June, of a planned 4-yr study we continued to collect information that will allow us to describe the processes that influence differences in the density of Townsend's ground squirrels (*Spermophilus townsendii*) among habitats and among years. We extended our collection of basic demographic data from our 20 study sites that differ in vegetation type, fire history, and history of tracking by armored vehicles. We believe that ground squirrel populations are at times food limited so we have focused on several factors that may directly influence energy flow through the system. These include the influence of habitat type on activity budgets, the role of microclimate in influencing activity budgets, the influence of habitat type on diet and body mass dynamics, and the role of dietary and endogenous fats in overwinter survival.*

To aid in the interpretation of hole counts as a measure of squirrel abundance we investigated the number of entrances in burrow systems and their spacing in different habitat types. We also initiated an investigation of hole survivorship, and counted active holes on the sites for which we have demographic information.

To address the possibility that parasites could be contributing to demographic differences in these social animals, we initiated a survey of intestinal parasites and blood serum, using both fecal material and necropsy. We found stress-related ulcers in 12% of squirrels, and more of these on high-density burned sites than on lower-density sites. Both *Hymenolepis* cestodes and *Rictularia* nematodes were more prevalent on high-density burned sites.

Mass dynamics indicate that ground squirrels will have extremely low overwinter survival from June 1992 to January 1993, probably as a result of drought conditions. We expect that densities in all habitats will be very low during the 1993 season.

■ OBJECTIVES

1. To continue to make significant progress toward the goals of determining whether Townsend's ground squirrel densities, survival rates, and productivity differ:
 - a) among habitat types.
 - b) between areas that have been subjected to tracked vehicle operations over a long period of time and those that have not.
 - c) between burned and unburned areas.
 - d) between burned areas that have been seeded and those that have not been seeded.
2. To ordinate sites according to vegetation coverage, to see how positioning of individual sites changes with year and season, and to interpret observed changes.
3. To describe how aspects of hole morphology vary among habitats, and to evaluate the usefulness of holes as indicators of Townsend's ground squirrel density.
4. To determine whether behaviors of Townsend's ground squirrels differ among sexes, ages, and habitat types.
5. To understand the role that microclimate plays in influencing foraging behavior.
6. To investigate the role of fat in influencing patterns of torpor and to describe the relationship between fat levels, torpor, and survival in different habitats.
7. To determine the pattern of parasite prevalence, and the effects of date, squirrel density, habitat, age, and sex on these patterns.
8. To determine effects of parasitism on weight and female reproductive rates.

METHODS

Study Sites

Sites are identical to those described previously (Van Horne et al. 1991), except that the 2 shadscale sites outside the Orchard

Training Area (OTA) were eliminated because too few animals were captured (< 5 adults total) to justify the time and effort involved in trapping. These were replaced with Big Sagebrush (*Artemisia tridentata*)-Winterfat (*Ceratoides lanata*) mosaic sites; designators 3a and 3b Table 1 and Fig. 1.

Table 1. Site pairs for sampling of Townsend's ground squirrels in the Snake River Birds of Prey Area.

Habitat type	Designators
Winterfat outside the Orchard Training Area (OTA)	1a, 1b
Sagebrush outside the OTA	2a, 2b
Sagebrush/Winterfat outside the OTA	3a, 3b
Burned Sagebrush inside the OTA	4a, 4b
Sagebrush inside the OTA	5a, 5b
Burned Winterfat outside the OTA	6a, 6b
Burned Sagebrush outside the OTA	7a, 7b
Burned and Seeded Winterfat outside the OTA	8a, 8b
Sagebrush inside the OTA tracked in 1992	9a, 9b
Burned Sagebrush inside the OTA tracked in 1992	10a, 10b

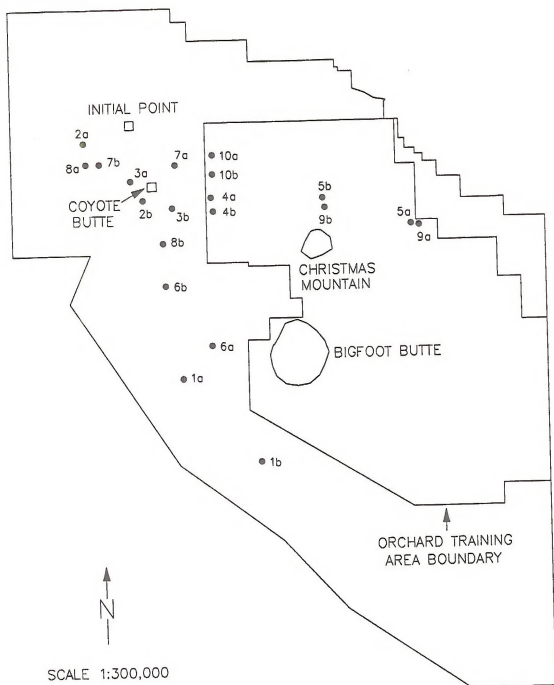


Fig. 1. Study site locations in the Snake River Birds of Prey Area (SRBOPA) near Boise, Idaho, 1992 (see Table 1 for site types).

Density Estimation

General methods of livetrapping, handling and marking animals are described in Van Horne et al. (1991) and Schooley et al. (1993). We made 2 major changes in these methods. First, we made changes to avoid swamping of traps and technicians during juvenile emergence, to get more accurate information for estimating ground squirrel production by site (Note: hereafter "ground squirrel" will refer to Townsend's ground squirrel, *S. townsendii*). We used the number of adult females captured during the first part of the season on each site as a basis for shrinking trapping grids on high-density sites at the time of juvenile emergence (Table 2). We also temporarily suspended trapping during the peak of juvenile emergence on sites where 0 or 1 adult females were trapped so we could concentrate our effort on the high-density sites. Second, we changed our trapping scheme from distinct trapping "cycles" of several consecutive days duration in 1991 to single-day occasions in 1992. Thus we trapped each site on average 1 day each week. This latter change required a change in population estimation techniques from "closed" population models (such as those described by Otis et al. 1978) to "open" population models. These models, basically the Jolly-Seber model and modifications of it (see Pollock et al. 1990), allow for animals to enter or leave a population (through birth, death, emigration, and immigration) over the time period during which mark-recapture data are collected. Because our 1992 trapping occasions were spread over several months, during which birth, death, and migration were occurring, the open population models were clearly appropriate. However, we were able to base abundance estimates, N , upon

the special case of the Jolly-Seber model which assumes no recruitment.

Analyses were run separately for adults and juveniles, and by sex within age group. Adult populations were estimated from data collected during the time from emergence from hibernation to just prior to grid shrinkage. Where sites were not shrunk, adult densities were estimated for the period prior to when juveniles were first caught on that site, or up to when trapping was suspended to concentrate effort on higher density sites.

Juvenile population estimation focused on the period beginning with emergence and ending 30 April. This end date is somewhat arbitrary; this period represents what we feel is the maximum time period during which juveniles caught on a site were produced on or very near the trapping grid, and were not immigrants. Although Jolly-Seber models can handle immigration, our primary interest was to estimate numbers of juveniles produced on a site.

The same general procedures were followed for both adult and juvenile estimation: capture data as entered from trapping records were summarized into capture history matrices (see Otis et al. 1978) and analyzed by program JOLLY (Pollock et al. 1990). Of the 5 models available in program JOLLY, model A, the "no recruitment" model was selected as most logically appropriate for our purposes. This model assumes there are no additions to the on site population during the time interval of interest. Only deaths and emigration are allowed. Thus model A is a special case of the Jolly-Seber model. From this model, we get an estimate of population size at the beginning of the time interval. For adults,

Table 2. Trapping effort for Townsend's ground squirrels on 20 study sites at the Snake River Birds of Prey Area, 6 February-17 June, 1992.

Site	Grid size (ha) ^a		Date of grid shrinkage	Number of days trapped	Number of sessions	Number of trap sets	
	Adult phase	Juvenile phase				Grid	Assessment line
1a	9.00	9.00		20	50	2,695	846
1b	9.00	9.00		19	48	2,588	846
2a	9.00	9.00		11	28	1,285	297
2b	9.00	9.00		12	33	1,756	450
3a	9.00	9.00		11	31	1,653	414
3b	9.00	9.00		19	53	2,875	927
4a	2.25	1.00	25 Mar	17	40	2,411	684
4b	2.25	1.00	26 Mar	18	46	2,758	792
5a	4.50	2.25	4 Apr	21	50	2,835	882
5b	4.50	2.25	26 Mar	20	44	2,571	774
6a	9.00	9.00		12	32	1,485	405
6b	4.50	2.25	1 Apr	19	51	3,015	900
7a	2.25	1.00	1 Apr	16	43	2,539	756
7b	2.25	1.00	2 Apr	18	50	2,651	882
8a	2.25	1.00	30 Mar	19	49	2,664	864
8b	2.25	1.00	30 Mar	18	50	2,832	873
9a	2.25	1.00	31 Mar	20	53	2,966	936
9b	4.50	2.25	29 Mar	19	46	2,510	810
10a	2.25	1.00	22 Mar	18	49	2,882	801
10b	4.50	1.00	23 Mar	19	48	2,867	819
Total				346	894	49,838	14,958

^a We reduced the grid size of 4.50- and 2.25-ha sites after our first capture of a juvenile. Decisions to reduce grid sizes were based on the number of reproductive females captured during the adult phase.

this means the population emerging from hibernation, and for juveniles the population emerging from natal burrows. This model assumes that animals first captured later in the time interval were actually in the population from the beginning. This does not seem to be an unreasonable assumption for these animals in the time periods we selected, as there was relatively little immigration or emigration until juveniles became independent later in the season. Population estimates for any later time in the time interval can be obtained by applying the appropriate survival rate calculated by the same model.

When data were too sparse, or otherwise unsuitable for population estimation using program JOLLY, the number of distinct individuals captured in the time interval was used as an index to population size. Although this index (also known as Minimum Number Alive) is biased toward underestimation of density, we felt it gave reasonable and quick estimates when captures were few, and was the only reasonable alternative when program JOLLY failed to provide good estimates.

The final step in density estimation was to calculate an area for the population estimates we derived. This was accomplished using data from assessment lines to calculate an additional strip width to add to the actual area of the trapping grid, producing an adjusted effective area trapped. Computation of this strip width was based on the proportion of tagged individuals to total individuals found in assessment line traps at increasing distances away from the trapping grid boundary. These proportions were weighted by this distance, with non-zero proportions furthest from the grid weighted more heavily. This method of calculating

effective trapping area differs somewhat from the method used in 1991, which did not contain a weighting factor. We feel that the method used here is an improvement, but more time will be needed to properly develop an estimator based on appropriate theory (or to feel comfortable about any existing published approach). Data were pooled within open and shrubby habitat types to provide sufficient information on strip width; however, time periods coincided with those for which population estimates were computed.

Survival Estimation

Two types of survival rates were computed: a minimum rate of survival from 1991 to 1992 based on recaptures in 1992 of animals tagged in 1991, and an average daily survival rate in 1992 for adults and juveniles based on 1992 capture data. The latter were calculated by computing site and age-specific daily survival rates from the no-recruitment model in program JOLLY, and averaging these across all sites for which sufficient data for estimates were available. Although individual site-specific rates did not seem reasonable in most cases (due to large standard errors), we feel that their average is probably close to the actual overall daily survival rate. More reasonable site-specific survival rates will require more sophisticated modeling techniques (using a program such as SURGE [Lebreton et al. 1992] and/or SURVIV [White 1983]) and could not be done in time for this report, but will be completed prior to next year's report.

SURGE and SURVIV will also be used for annual survival rate estimates, which will be an improvement over the recapture rates reported here. Recapture rates such as these should only be loosely interpreted as

"annual" survival rates as it is difficult to determine the appropriate corresponding time interval. For example, an individual tagged early in 1991 may not be recaptured until late in 1992, covering a time span of nearly 18 months. Another individual of the same age and sex may be tagged late in 1991 and recaptured early in 1992, a time span of just 7 months. Thus it is important to apply the strictest interpretation to these recapture rates: they are simply the proportions of animals tagged in 1991 that are caught again some time in 1992. All we know, then, is that they survived between years, did not disperse to an area not covered by our traps, and were captured again in 1992.

Necropsy

Necropsied animals were used to describe embryo production, for collection of fat and blood serum samples, and for investigation of parasites and their locations. Nine adult squirrels were collected from a burn site located near Coyote Butte in February, and 1 adult squirrel/site/month was collected adjacent to all 20 sites from February through June, when possible. One juvenile/site/month from emergence (April) until immersion also was collected adjacent to each site. A total of 122 animals was collected and kept frozen. Carcasses were later thawed and for females all placental scars or fetuses were counted in both uterine horns.

Hole Counts

To evaluate the utility of densities of ground squirrel holes for predicting densities of ground squirrels, we censused ground squirrel holes on our 20 study sites between 1 June and 8 June 1992. With assistance of personnel from Study 5, we counted all

holes on the grids used during the adult-only trapping phase (2.25, 4.0, or 9.0 ha). We classified assumed ground squirrel holes as either active or inactive, based on animal sign, with active holes being those believed to have been recently used by a ground squirrel. We also categorized each hole as high certainty or low certainty, which referred to the level of confidence the observer had when assigning an activity class. Therefore, we used 4 classes for holes: active high, active low, inactive high, inactive low. To examine relationships between densities (number/ha) of holes and ground squirrels, we compared 3 measures of hole density with 1 measure of ground squirrel density. Our measures of holes were TOTAL (sum of counts for all 4 classes), ACTIVE (active high + active low), and POSSIBLY ACTIVE (active high + active low + inactive low). We correlated (Spearman's Rank Correlation Coefficients, R_s) these measures of hole densities with total ground squirrel density, which was the sum of estimates of adult densities at emergence and an index of juvenile densities prior to 30 April (total number of individuals captured/adjusted grid area). We performed correlations for all sites combined, and separate analyses for burned sites ($n = 10$) and shrub sites ($n = 10$).

Burrow Morphology and Use

To examine burrow morphology, P. Sharpe blew smoke through burrow systems on 2 sites in each of 6 habitat types (burned sagebrush, winterfat/sagebrush mosaic, OTA sagebrush, sagebrush outside the OTA, seeded winterfat, and winterfat). A single transect was established 100 m outside the established trapping grid at each site (so as not to interfere with ground squirrels involved in the trapping study), and 10

ground squirrel burrows were located along each transect. Burrows were at least 10 m apart so that different entrances on the same burrow system were not used. Colored smoke bombs (available at fireworks outlets) were lowered into a hole and the smoke was blown through the system with a leaf blower. Additional holes were blocked with rags as the smoke was emitted to force the air to move through the burrow system. After we were satisfied that all holes had been located (usually after 1-3 smoke bombs), the greatest distance between 2 holes was measured and the number of holes that a ground squirrel could use was counted. There were often small "air holes" or collapsed holes that emitted smoke but did not appear usable by ground squirrels. These holes were noted but were not included in calculations of number of holes or distances between holes.

When possible during behavioral observations, P. Sharpe identified and tagged holes being used by marked ground squirrels to determine the number of holes used per ground squirrel, and the number of ground squirrels that used the same hole.

Hole Phenology

Two factors that can potentially affect the relationship between the density of ground squirrels and the density of active ground squirrel holes on a site are the stability of ground squirrel holes among years, and their patterns of use. Such information is also of interest in terms of basic natural history of the Townsend's ground squirrel. We randomly selected 50 ground squirrel holes each on 6 trapping grids between 11 and 17 June 1992. We marked and numbered holes from 3 site pairs outside of the OTA, which included sagebrush habitat (Sites 2a, 2b),

burned sagebrush (7a, 7b), and winterfat (1a, 1b), and recorded their locations. We attempted to mark active ground squirrel holes based on the criteria used for our extensive hole counts on all sites. However, the early emergence of ground squirrels, together with the rain that occurred in early June, removed most ground squirrel sign at holes and forced us to use less strict criteria; holes that were neither caved in nor filled with debris under these conditions were likely to have been active during the 1992 season. A single observer (R. L. Schooley) selected most holes (289 of 300), and he will survey the holes in subsequent years. We will survey these holes in early March (before juveniles emerge) and in mid April (before most adults immerge) in 1993 and 1994. We will record whether each hole is present and also its status (active or inactive). The results of this study may be especially useful for interpreting the 1993 hole counts, given that we expect few juveniles produced in 1992 to survive. A time lag between a reduction of ground squirrel densities and a subsequent reduction of ground squirrel hole densities could affect the usefulness of active ground squirrel holes as an index of ground squirrels.

Behavioral Observations

Activity Budgets.--Data on Townsend's ground squirrels were collected from 9 February through 4 June 1992 by P. Sharpe. Most observations were made on squirrels that had been uniquely marked with hair dye (Clairol Nice 'n Easy® blue-black) on 6 separate sites (Sites 1a, 3b, 4a, 5b, 9b, 10a). On Sites 1a and 3b there were few marked individuals, so observations were often made on unmarked individuals when an age class (and sometimes sex for lactating females) could be determined. After juvenile

emergence, observations on juveniles of unknown sex were often made on many of the sites because there were few marked individuals.

Observations were made from a portable 3-m high hunter's stand (Hunter's Equipment, Inc., San Angelo, TX) using a 15-60 zoom spotting scope mounted on the stand's railing. Observations of a focal animal's behavior, distance to cover, distance to the most recently used burrow (if known), and distance moved were recorded every 20 sec on a Polycorder electronic notebook (Omnidata International, Inc., Logan, UT). At the beginning of each observation period and at 15-min intervals thereafter, temperature, wind speed, and percent cloud cover were also recorded. Each focal animal was observed for a minimum of 10 min per day and a maximum of 30 min. Initial attempts to observe ground squirrels from the time they emerged from a hole until they immersed again were discontinued because of small sample sizes. The ground squirrels often remained above ground for extended periods (2 + hrs/trip), making it difficult to locate animals as they emerged. Instead, activity was recorded in an "observation string" from the time ground squirrels were first observed until they either disappeared in a hole for more than 5 min (observation periods rarely ended with a ground squirrel in the burrow), disappeared from sight for more than 3 min (this often occurred on shrub sites), or were observed for a full 30 min. If a ground squirrel was not observed for 30 min, we tried to relocate the individual during the day for further observations. A scan sample was made at 15 min intervals (or at the end of an observation period) to determine the proportion of the day in which animals were above ground. Scans were made within a

specified area each day on Sites 4a and 10a (usually certain quadrants within the overall grid which could be easily observed) and were made over as much of the site as could be seen on the remaining sites. A measure of relative predation pressure by raptors was made by recording the number of raptors (not including ravens) seen flying over the 9 ha site during each 15-min interval; because of the relatively flat topography it was not difficult to view the relevant airspace. Additional observations or comments were recorded on a microcassette for later transcription.

The mean proportions of time spent in each activity were summarized for each animal and arcsine-transformed prior to analysis. Only observations in which the animal was visible were included in calculating proportions. When testing for age or sex differences, each sample point represents the mean value for a single animal of known age or sex. Data from all observed animals were used when comparing sites or site types, and only adults were used when comparing reproductive periods (gestation, lactation, post-lactation.) When testing for activity differences between the reproductive periods some individuals may be represented in more than 1 reproductive period. The onsets and durations of each reproductive period were estimated using trapping data, data on the length of gestation and lactation periods (Armitage 1981), and observational data. ANOVA tests were used to test for differences among site, sex, and age classes. Significant ANOVA's were investigated using Tukey's Studentized Range Test.

Environmental Factors.--Environmental factors, such as temperature, radiation, and wind speed were measured throughout the day in conjunction with the behavioral

observations to determine if there were relationships between environmental conditions and ground squirrel activity. All equipment was obtained from Campbell Scientific, Inc., Logan, UT.

The weather equipment was wired to a CR10 measurement and control module via a wiring panel, all housed inside a fiberglass weather-resistant enclosure. Power was supplied by a rechargeable battery that was float-charged by a MSX10 solar panel. Temperature and relative humidity were measured at about 10 cm above the ground by a 207 Temperature and Relative Humidity probe housed within a UT12P radiation shield. Wind speed was measured at about 30 cm above the ground with a "Met One Wind Speed Sensor." Two LI-COR silicon pyranometers were used, 1 to measure incoming solar radiation from the sky and 1 to measure outgoing or reflected solar radiation from the ground. Thermal radiation was measured with a modified REBS net radiometer. A copper-constantan thermocouple was placed inside half a steel can which was painted black inside and then attached to the downward facing plastic dome on the net radiometer. The thermal radiation striking the lower dome was calculated by measuring the temperature within the can and computing the radiation from a blackbody of that temperature. Thermal radiation from the sky was calculated by adding the thermal radiation striking the covered dome to the reading of the net radiometer and subtracting the incoming solar radiation measured with the pyranometer. This allowed us to calculate all incoming and outgoing sources of radiation.

In addition to the weather equipment, hollow bronze mounts of ground squirrels were

made in basking, standing, and sitting positions and covered with a ground squirrel pelt. A thermocouple was placed inside each ground squirrel so their temperatures could be monitored by the CR10. This would enable a measurement of the true environmental temperature (T_e) described by Bakken and Gates (1975), which includes the effects of temperature, radiation, and convection. Four sets of ground squirrels were made so that temperatures could be monitored simultaneously in different microhabitats (i.e., sun and wind, sun and no wind, shade and wind, shade and no wind). These data will eventually be used to create a climate-space diagram which will describe those conditions under which ground squirrels can remain above ground while keeping their body temperatures within their thermal equilibrium (e.g., Morhardt and Gates 1974). All equipment was set up and removed each day because it could not be left in the field due to possible human or animal interference.

Vegetation, Diet, and Habitat Manipulations

Vegetation was sampled during 3 different periods; 19 February - 24 February, 13 April - 15 April, and 24 May - 30 May using procedures reported in Van Hone et al. (1991). These corresponded with 3 periods in which fecal samples were collected for dietary analysis; 6 February - 18 March (mostly mid-February), 6 April - 3 May (mostly mid-April), and 16 May - 1 June. Fecal samples have not yet been analyzed.

Vegetation from the second of 2 sampling periods in 1991 and from each of the 3 sampling periods in 1992 was used to calculate reference axes in a detrended

correspondence analysis (CANOCO, ter Braak 1988). Samples of each site during each of these periods were plotted onto the reference axes so we could see whether site pairs and sites in the same habitat categories were grouped, and to detect changes in vegetation within 1992 and between years. We included only those variables that represented potential food items (detected in fecal material in 1991 [Van Horne et al. 1991]), as we expect these to have the most straightforward demographic effect. We included the common genera *Artemisia*, *Bromus*, *Ceratoides*, and *Poa*. *Salsola* and *Sisymbrium* were combined, as were the mosses and lichens. The remaining grasses were combined into a single category dominated by *Elymus*, as were the remaining forbs, dominated by *Ranunculus*.

Experimental tracking manipulations were carried out on 4 sites; 10a, 10b, 9a, and 9b. Approximately 33% of the surface area of each of these sites was tracked by an M-1 armored vehicle during 26-27 June, after most of the squirrels had immersed. Patterns of behavior and demography on these sites will be compared with those on control sites in 1993 and 1994 to ascertain the short-term effects of tracking by armored vehicles.

Role of Fats

Role in Survival.--Overwinter survival of ground squirrels of known body composition (measured in June 1991) was assessed by examining capture records through April 1992. Mass and body composition of ground squirrels was estimated during regular live-trapping efforts on 7 sites (1a,b 4a, 5a,b, 8a,b) in February and on 8 sites in May, representing sites with (1a,b, 5a,b) and without (4a,b, 8a,b) shrub cover. Techniques for measuring body composition were

described in Corn and Van Horne (1991). The May sample was drawn using an updated version of the TOBEC (Model SA-2), integrated with a laptop computer. Because body composition readings may not be identical between the 2 machines used in the study thus far, a calibration curve will be established for each machine to relate TOBEC indexes to lean mass of ground squirrels. Three sites (4a, 8a, and 8b) were sampled at 1-week intervals in May to assess the body composition changes associated with the mass loss observed during the drought.

Fat Deposition Patterns.--Adipose tissue samples were collected from abdominal fat pads of ground squirrels sacrificed for parasite surveys plus additional animals collected for calibration of the TOBEC. Samples were stored in chloroform:methanol (2:1, vol:vol) or 0.9% NaCl and frozen immediately. Fatty acids were extracted, transesterified, and characterized using techniques described in Florant et al. (1990), except that Bcl_3 was used to make the fatty acid methyl esters.

Vegetation was sampled on each of the 8 sites for fatty acid (FA) analysis. Plants composing the major diet items (based on fecal analysis) were collected along 300m transects running in a randomly-chosen direction on each site. Two composite samples and 1 sample for estimating percent water were collected for each plant species and plant part. Common plants such as *Poa*, *Artemisia*, and *Ceratoides* were sampled by collecting the individual plant closest to a point every 10m along the transect until 10 plants had been sampled. For shrubs, growing tips of branches on 4 sides of the plant were sampled, and leaves, stems and flowers or seed heads were separated. For

Poa, only green vegetation was collected and seeds, leaves, and root crowns were separated. Uncommon types, like *Elymus*, *Stipa*, and green *Poa* on sites where it was mostly dried out, were sampled by collecting every individual within 0.5 m of the transect. Samples were frozen for fatty acid analysis.

Laboratory Experiments.--Laboratory experiments with captive ground squirrels were not possible this year, because captive animals gained large amounts of weight immediately after arousing from hibernation, making it unlikely that a diet effect would be detected. A preliminary experiment with a few ground squirrels captured in May is presently being conducted, using semi-purified diets with 10% fat either in the form of hydrogenated coconut oil with a small amount of canola oil added to provide essential fatty acids (low-unsaturated fat diet), or as sunflower oil (high-unsaturated fat diet). After 2 months on the diet, adipose tissue samples were obtained from anesthetized animals and FA composition was determined. Results of this preliminary experiment, and progress on a more complete experiment, will be reported in the 1993 Annual Report.

Parasites

Individual Sampling.--Collection procedures for necropsies are described under the methods for fat deposition patterns. Fresh fecal pellets also were obtained from each squirrel prior to necropsy and placed in 2.5% (w/v) aqueous potassium dichromate ($K_2Cr_2O_7$), and later examined for eimerian oocysts and helminth ova using sucrose flotation methods (Duszynski et al. 1982, Stout and Duszynski 1983). Ground squirrels were weighed and euthanized with Halothane. Immediately following death,

3-ml blood samples were obtained via vena cava puncture, placed in 13 X 110-mm glass screw top vials and allowed to clot at 4 °C overnight. Serum was removed with a clean pipette, and frozen in 2-ml nunc tubes (Intermed). Thin blood smears also were made for each animal. Carcasses were frozen immediately and stored at -5 °C. All material was transferred to the University of New Mexico (UNM) in Albuquerque for analysis.

Blood smears were stained with Giemsa-Wright and scanned for blood parasites at 1125X using a Leitz Dialux microscope. Serum was frozen at -20 °C for future protein electrophoresis. The gastro-intestinal tract of all squirrels was removed, and stomach and intestinal tissue and ingesta were examined at 2x under a dissecting scope. Cecal and rectal ingesta were rinsed through a 250- μ m sieve with tap water to remove excess debris. Particles remaining in the sieve were transferred to a petri dish and examined under the dissecting scope. All observed parasites were fixed in 10% buffered formalin.

Nematode species were identified to genus by microscopic examination using lactophenol wet mounts. Cestodes were fixed for 24-48 hrs and rinsed for 1 hr each in tap water, 5% ETOH, 20% ETOH, and 50% ETOH before storage in 70% ETOH. Cestodes were stained overnight in Grenachers-Borax Carmine, and then fully dehydrated through a 1-hr series of ETOH baths (85%, 95%, 100%). Specimens were cleared in terpineol and permanently mounted in Canadian Balsam. Appropriate specimens of all helminths will be deposited with the U.S. National Museum Parasite Collection in Beltsville, MD.

Parasite Population Sampling.--Sites for parasite work were chosen based on 1991 adult ground squirrel density estimates and habitat (Table 3). Sites 4a and 4b were high-density open sites dominated by Sandburg's bluegrass *Poa secunda*. These 2 sites were historically covered with big sagebrush, but burning has eliminated all but a few shrubs. Sites 5a and 5b were medium-density sites with moderate density sagebrush. Sites 2a and 2b were low-density sites thickly covered with sagebrush. Sites 1a and 1b were included because densities on 2a and 2b were so low that we did not think there would be enough hosts to provide adequate sample sizes. This proved correct.

One to 5 fecal pellets were obtained from the first 20 adult females/trapping day/site, the first 20 males for 1 trapping day/site in the beginning, middle, and end of the season (3 days total), and the first 10 juvenile females/trapping day/site upon emergence (April).

RESULTS AND DISCUSSION

Livetrapping

During 1992, we captured 2,558 individual ground squirrels (442 adult males, 677 adult females, 645 juvenile males, 786 juvenile females, and 8 that had conflicting records of either sex or age). We marked 2,108 individuals with PIT tags (669 new adults, 1,439 juveniles). Our efforts resulted in 8,593 captures, nearly double the 4,767 captures made during the previous year.

We trapped each of our 20 sites on 11-20 days ($\bar{x} = 17$) from 6 February to 17 June 1992 (Table 2). Four sites with low densities of adult squirrels (2a, 2b, 3a, 6a) were trapped on fewer occasions than other sites. We temporarily suspended effort on these sites during April while we doubled technician effort on 7 sites with high adult densities (4a, 4b, 6b, 7a, 8b, 10a, 10b). On most days we trapped each site for 2 or 3

Table 3. Adult Townsend's ground squirrel density estimates and fecal collection site characteristics at the Snake River Birds of Prey Area, 1992.

Site	Dominant Vegetation 1991	% Dominant Vegetation Cover, 1991	Density Estimate (Adults/ha)	
			1991	1992
1a	<i>Ceratoides lanata</i>	15.2	2.62	0.81
1b	<i>C. lanata</i>	15.2	0.91	0.90
2a	<i>Artemisia tridentata</i>	42.1	0.70	0.09
2b	<i>A. tridentata</i>	25.7	0.25	0.54
4a	<i>Poa secunda</i>	28.3	13.60	23.04
4b	<i>P. secunda</i>	29.7	9.25	28.24
5a	<i>A. tridentata</i>	25.7	6.49	6.99
5b	<i>A. tridentata</i>	19.4	7.59	12.68

sessions with a mean of 56 traps per session on the grid (range 23-93 traps, $n = 894$ sessions). We usually set an additional 18 traps on assessment lines each session. Our total effort resulted in 65,749 traps set. The 49,838 traps set on grid (Table 2) was a marked increase from 1991 when we set 19,329 traps on grid. The increased trapping effort this year was due to (1) less effort expended on grid establishment, (2) reduced effort counting and mapping burrow openings, (3) fewer days with weather inappropriate for trapping, (4) an increased area trapped on most sites, and (5) an increased number of traps per session.

Density Estimates.--All results reported here are considered preliminary, and are likely to be modified as improved methods of estimation are applied and/or developed. However, we feel confident that general relationships, such as relative density among sites, will not change substantially.

We had sufficient sample sizes of adults post-emergence to estimate population sizes by sex using the program JOLLY "no-recruitment" model on 13 of 20 sites (Table 4). For the remaining sites (1a, 1b, 2a, 2b, 3a, 3b, and 6a), we used the Minimum Number Alive (MNA) as an estimate of population size (Table 4).

Although sample sizes for juveniles post-emergence were sometimes large (over 100 individuals), we were unable to use models for which software is currently available to compute realistic population estimates. We are in the process of modifying existing JOLLY "no-recruitment" software to allow us to constrain recapture and survival rates and are still working on refinement of our

survival rate estimates. Results of this analysis will be included in next year's annual report. This is partially due to a high proportion of animals captured once but never recaptured (Table 5). Hence for now we report MNA, adjusted for effective trapping area, as an index to density for juveniles by sex for all 20 sites (Table 6). Statistical comparisons between sites were not computed as they were deemed to be premature given the quality of the estimates; clearly the burned sites had higher adult and juvenile densities than unburned sites, and sites inside the OTA had higher adult and juvenile densities than sites outside the OTA. This is the same pattern that was reported for 1991 (Van Horne et al. 1991).

Survival Estimates.--The proportions of ground squirrels tagged in 1991 and recaptured at any time in 1992 are "recapture rates" that represent an average minimum survival rate from 1991 to 1992 (Table 7). Males tagged as juveniles had the lowest recapture rate for all sites ($\bar{x} = 0.19$ for all sites), whereas adult females had the highest ($\bar{x} = 0.61$), followed by adult males ($\bar{x} = 0.50$) and juvenile females ($\bar{x} = 0.41$). No particular pattern was noted with regard to habitat type; this will be examined when more appropriate survival rates are available. Low rates of recapture for juvenile males are not surprising because emigration is highest for this group in many ground squirrels (Armitage 1981).

Average daily survival rates in 1992 were estimated for adults as 0.9956 (SE = 0.0061), and for juveniles as 0.9638 (SE = 0.0071). These estimates were calculated over the same time periods as the density

Table 4. Townsend's ground squirrel density estimates for sites in the Snake River Birds of Prey Area, 1992, adults at emergence.

Site	Sex	MNA ^a	\hat{N}	Grid			Strip Width (m)	Adjusted Grid Area (ha)	Density (#/ha)
				Area (ha)	Length (m)	Width (m)			
1a	M	3	3	9.00	300	300	36.28	11.20	0.27
	F	6	6	9.00	300	300	36.28	11.20	0.54
1b	M	4	4	9.00	300	300	36.28	11.20	0.36
	F	6	6	9.00	300	300	36.28	11.20	0.54
2a	M	0	0	9.00	300	300	36.28	11.20	0.00
	F	0	0	9.00	300	300	36.28	11.20	0.00
2b	M	5	5	9.00	300	300	36.28	11.20	0.45
	F	1	1	9.00	300	300	36.28	11.20	0.09
3a	M	1	1	9.00	300	300	36.28	11.20	0.09
	F	1	1	9.00	300	300	36.28	11.20	0.09
3b	M	16	16	9.00	300	300	36.28	11.20	1.43
	F	8	8	9.00	300	300	36.28	11.20	0.71
4a	M	22	22	2.25	150	150	61.17	4.14	5.32
	F	45	56	2.25	150	150	29.91	3.16	17.72
4b	M	34	37	2.25	150	150	61.17	4.14	8.94
	F	40	61	2.25	150	150	29.91	3.16	19.30
5a	M	20	22	4.50	150	300	36.28	6.15	3.58
	F	21	21	4.50	150	300	36.28	6.15	3.41
5b	M	31	34	4.50	150	300	36.28	6.15	5.53
	F	44	44	4.50	150	300	36.28	6.15	7.15
6a	M	0	0	9.00	300	300	61.17	12.72	0.00
	F	0	0	9.00	300	300	29.91	10.81	0.00
6b	M	22	22	4.50	150	300	61.17	7.31	3.01
	F	44	44	4.50	150	300	29.91	5.86	7.51
7a	M	19	19	2.25	150	150	61.17	4.14	4.59
	F	35	43	2.25	150	150	29.91	3.16	13.61
7b	M	20	22	2.25	150	150	61.17	4.14	5.32
	F	21	25	2.25	150	150	29.91	3.16	7.91
8a	M	18	24	2.25	150	150	61.17	4.14	5.80
	F	25	29	2.25	150	150	29.91	3.16	9.18
8b	M	21	26	2.25	150	150	61.17	4.14	6.28
	F	35	38	2.25	150	150	29.91	3.16	12.03
9a	M	16	16	2.25	150	150	61.17	4.14	3.87
	F	15	15	2.25	150	150	29.91	3.16	4.75
9b	M	37	47	4.50	150	300	36.28	6.15	7.64
	F	27	27	4.50	150	300	36.28	6.15	4.39
10a	M	27	27	2.25	150	150	61.17	4.14	6.52
	F	47	61	2.25	150	150	29.91	3.16	19.30
10b	M	43	47	4.50	150	300	61.17	7.31	6.43
	F	56	63	4.50	150	300	29.91	5.86	10.75

^a Minimum number alive

Table 5. Proportion of juvenile Townsend's ground squirrels captured between emergence and 1 May 1992 that were captured only once in that time interval (PONCE).

Site	Sex	PONCE	N
1a	F	0.61	18
	M	0.75	16
1b	F	0.40	10
	M	0.20	5
3b	F	0.50	18
	M	0.33	12
4a	F	0.31	84
	M	0.66	47
4b	F	0.43	103
	M	0.53	75
5a	F	0.34	29
	M	0.22	23
5b	F	0.40	15
	M	0.75	8
6b	F	0.36	104
	M	0.40	55
7a	F	0.53	72
	M	0.38	73
7b	F	0.37	40
	M	0.40	35
8a	F	0.24	49
	M	0.35	37
8b	F	0.24	63
	M	0.41	32
9a	F	0.15	74
	M	0.29	14
9b	F	0.35	17
	M	0.13	23
10a	F	0.25	113
	M	0.46	80
10b	F	0.35	99
	M	0.46	35

Table 6. Townsend's ground squirrel density indexes for sites in the Snake River Birds of Prey Area 1992, juveniles at emergence.

Site	Sex	MNA*	Grid			Strip Width (m)	Adjusted Grid Area (ha)	Density (#/ha)
			Area (ha)	Length (m)	Width (m)			
1a	M	14	9.00	300	300	37.34	11.38	1.23
	F	14	9.00	300	300	37.34	11.38	1.23
1b	M	3	9.00	300	300	37.34	11.38	0.26
	F	6	9.00	300	300	37.34	11.38	0.53
2a	M	0	9.00	300	300	37.34	11.38	0.00
	F	0	9.00	300	300	37.34	11.38	0.00
2b	M	0	9.00	300	300	37.34	11.38	0.00
	F	0	9.00	300	300	37.34	11.38	0.00
3a	M	0	9.00	300	300	37.34	11.38	0.00
	F	0	9.00	300	300	37.34	11.38	0.00
3b	M	7	9.00	300	300	37.34	11.38	0.62
	F	12	9.00	300	300	37.34	11.38	1.05
4a	M	38	1.00	100	100	47.12	2.16	17.56
	F	49	1.00	100	100	47.12	2.16	22.64
4b	M	53	1.00	100	100	47.12	2.16	24.49
	F	68	1.00	100	100	47.12	2.16	31.42
5a	M	11	2.25	150	150	37.34	3.51	3.13
	F	16	2.25	150	150	37.34	3.51	4.56
5b	M	7	2.25	150	150	37.34	3.51	1.99
	F	9	2.25	150	150	37.34	3.51	2.56
6a	M	0	9.00	300	300	47.12	12.05	0.00
	F	0	9.00	300	300	47.12	12.05	0.00
6b	M	35	2.25	150	150	47.12	3.89	9.01
	F	60	2.25	150	150	47.12	3.89	15.44
7a	M	45	1.00	100	100	47.12	2.16	20.79
	F	50	1.00	100	100	47.12	2.16	23.10
7b	M	22	1.00	100	100	47.12	2.16	10.16
	F	24	1.00	100	100	47.12	2.16	11.09
8a	M	22	1.00	100	100	47.12	2.16	10.16
	F	23	1.00	100	100	47.12	2.16	10.63
8b	M	20	1.00	100	100	47.12	2.16	9.24
	F	28	1.00	100	100	47.12	2.16	12.94
9a	M	8	1.00	100	100	37.34	1.89	4.24
	F	25	1.00	100	100	37.34	1.89	13.25
9b	M	8	2.25	150	150	37.34	3.51	2.28
	F	10	2.25	150	150	37.34	3.51	2.85
10a	M	53	1.00	100	100	47.12	2.16	24.49
	F	53	1.00	100	100	47.12	2.16	24.49
10b	M	23	1.00	100	100	47.12	2.16	10.63
	F	56	1.00	100	100	47.12	2.16	25.87

* Minimum Number Alive

Table 7. Proportions of Townsend's ground squirrels in the Snake River Birds of Prey Area tagged in 1991 and recaptured in 1992 (P Recap) by age (A = adult, J = juvenile) and sex (M = male, F = female, X = sex unknown).

Site	Age	Sex	P Recap	N
1a	A	M	0.25	4
		F	0.60	5
	J	M	0.25	8
		F	0.37	8
1b	A	M	1.00	2
		F	1.00	3
	J	M	0.00	3
		F	0.50	6
2a	A	M	0.00	3
		F	0.33	3
	J	M	0.00	4
		F	0.00	5
2b	A	M	0.00	1
		F	0.00	1
	J	M	0.00	3
		F	0.20	5
4a	A	M	0.20	5
		F	0.54	11
	J	M	0.17	24
		F	0.58	33
4b	A	M	0.57	7
		F	0.73	11
	J	M	0.17	42
		F	0.33	46
5a	A	M	0.67	12
		F	0.90	10
	J	M	0.05	19
		F	0.71	17
5b	A	M	0.56	16
		F	0.65	20
	J	M	0.32	38
		F	0.49	43
6a	A	M	0.00	1

Table 7. Continued.

Site	Age	Sex	P Recap	N
6b	A	M	0.40	5
		F	0.57	7
	J	M	0.00	8
		F	0.56	16
7a	A	M	0.67	9
		F	0.54	26
	J	M	0.11	70
		F	0.26	61
7b	A	M	0.50	8
		F	0.62	8
	J	M	0.27	11
		F	0.50	6
8a	A	M	0.80	5
		F	0.54	11
	J	M	0.14	28
		F	0.33	21
8b	A	M	0.50	6
		F	0.67	12
	J	M	0.09	22
		F	0.39	18
9a	A	M	0.27	11
		F	0.54	13
	J	M	0.21	28
		F	0.41	27
9b	A	M	0.54	11
		F	0.50	12
	J	M	0.42	19
		F	0.45	29
10a	A	M	0.38	13
		F	0.54	24
	J	M	0.27	33
		F	0.41	54
		X	0.00	1
10b	A	M	0.64	14
		F	0.71	21
	J	M	0.23	26
		F	0.52	42

estimates reported above. As expected, the adult survival rate was considerably higher than the juvenile rate.

Projected Improvements to Estimators.--

Estimates of density and survival rates presented in this report are, as noted, preliminary. Improvements to these estimates require either more sophisticated modeling techniques or modifications to existing software programs. Fortunately, they will not require development of new theory, with the possible exception of calculating an effective area for our trapping grids. Survival rates will be estimated using existing programs that enable customized modeling of time-specific survival and recapture rates. With data sets such as ours, selection of the best estimates may require fitting hundreds of different models (for a thorough review of model fitting techniques and philosophy see Lebreton et al. [1992] and Burnham and Anderson [1992]).

Density estimation requires improvements both in population size estimation and effective area estimation. Population estimates can be obtained by the same model-fitting procedures as will be used for survival rates; however, at this time the software programs available to do this (such as a SAS program written by K. Burnham, described in Burnham [1989]) do not contain the special "no recruitment" case that we believe is appropriate for our analyses. Fortunately, the modifications necessary to add this model are relatively simple, but as with any software changes must be carefully done and thoroughly tested before results can be used.

Determining effective trapping area will require more thought. Traditional methods using data from assessment lines (see Seber [1982] for review) are somewhat ad hoc, as are the methods we used in this and the 1991 annual reports. K. Burnham feels it should be possible to develop or justify a theoretically sound estimator using the data we have collected, and we will do so before the end of this project.

Chronology of Annual Activity and Reproduction

Adult Emergence.--We first observed multiple sightings of ground squirrels on 30 January 1992 in the general area of the OTA burn sites (4a, 4b, 10a, 10b). By our first trapping period (6-13 February 1992), adult males and females were captured on most sites (15 of 16) where densities were high enough to evaluate timing. The ratio of M:F captured, relative to average ratios for the year, suggested that females were still emerging during the second week of February on 4 shrub sites (1b, 5a, 9a, 9b). Although we know from trapping records that emergence of males and females did not differ by more than 2 weeks, the timing of our initial trapping did not allow us to detect smaller differences in emergence time. The early emergence of squirrels was probably related to the mild winter and early growth of grasses; Sandberg's bluegrass was already green on the OTA burn sites by 30 January. In future years, we will initiate live-trapping earlier to document possible sexual differences in timing of adult emergence.

Most males (89.8%, $n = 98$) captured during the initial trapping occasions (6-13 February)

had descended testes, and most males remained scrotal at least through February. We last captured a scrotal male on 17 March.

Adult females first showed evidence of lactation (based on enlarged nipples) during March on all sites; however, there were differences among sites in the timing of lactation (Fig. 2). Most females on 6 burned sites (4a, 4b, 6b, 7a, 10a, 10b) were lactating by early March (9-11), whereas on 3 burn sites (7b, 8a, 8b) and 4 sagebrush sites (5a, 5b, 9a, 9b) most females were not lactating until mid-March (15-23). Data were too sparse to determine when most females were lactating on our 2 winterfat sites (1a, 1b), but the date of first capture of a lactating female (Fig. 2) suggested that reproduction was also delayed on these sites.

Juvenile Emergence.--In general, the first capture of juveniles (Fig. 2) occurred earlier (22 March-1 April) on burned sites than on shrub sites (2 April-20 April), except at 1 sagebrush site (9a, 25 March). Juveniles were first captured on sagebrush site 5b nearly 1 month after their first capture on a *Poa*-dominated burn (20 April vs. 22 March). Juvenile emergence was not documented on 4 sites that were not trapped in April.

The earliest date on which a juvenile was caught may not be sensitive to differences in emergence patterns among sites due to the variability among individuals within sites. Therefore, we also examined the frequency distribution of first captures of juveniles, and determined the first date on which 50% of the individual juveniles had been captured on each site (median date). We recognize that timing of first captures of juveniles probably is a function of actual emergence

from burrows, growth and development rates and subsequent movement patterns, and perhaps densities and trapping probabilities. Different rates and timing of dispersal of individuals among sites also could bias this index. However, we believe this index generally reflected phenology of reproduction among sites. Juveniles on the 4 OTA burns and Site 8a emerged earliest (median date ranged from 2 to 12 April; Fig. 2), whereas juveniles on the other burned sites were intermediate (median date ranged from 19 to 23 April), and juveniles emerged latest on the shrub sites (median date ranged from 30 April to 14 May), with the exception again of sagebrush Site 9a (23 April). The late median date of winterfat Site 1a was probably due to delayed emergence and an influx of dispersing juveniles.

Adult Immergence.--Adult males immersed during May (Fig. 3). Although immergence patterns among sites did not seem strongly associated with habitat, males tended to immerge latest on the 4 burned sites inside the OTA (Fig. 3). Adult females began immergence in mid to late May, but individuals on some sites remained above ground until early June (Fig. 3). The last capture of adult females was later than that of adult males on 15 of 16 sites, with a mean of 16 days ($SE = 1.42$) between dates of last capture of individuals of each sex.

Juvenile Immergence.--Juveniles were last captured between 13 May and 17 June (Fig. 4). Juveniles tended to immerge latest on sagebrush sites inside the OTA and on winterfat sites. Juvenile females generally immersed later than juvenile males, although the pattern was not as strong as that for adults. Juvenile females were captured later

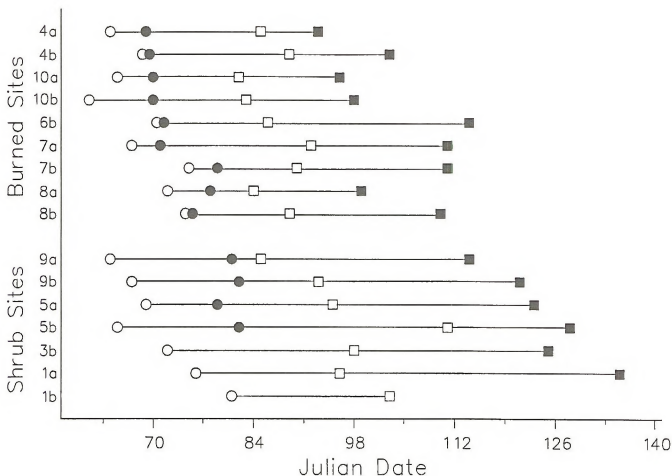


Fig. 2. Timing of reproductive events of Townsend's ground squirrels on 16 study sites, Snake River Birds of Prey Area, southwest Idaho, 1992. Sample sizes on 4 sites (2a, 2b, 3a, 6a) were too small to estimate timing of reproductive events. Open circles are the first dates that an adult female was captured with enlarged nipples, which indicated probable lactation. Closed circles are the median dates of lactation, which were the first dates when >50% of the individual adult females had enlarged nipples (we used >33% for site 5b because of overall low reproduction on this site). Open squares are the first dates that juveniles were captured. Closed squares are the median dates of juvenile captures, which represented the first date on which 50% of the individual juveniles had been captured.

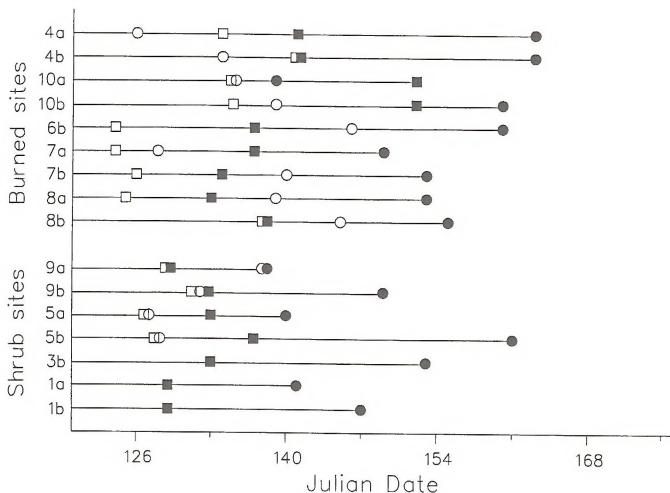


Fig. 3. Timing of emergence of adult male (squares) and female (circles) Townsend's ground squirrels on 16 study sites, Snake River Birds of Prey Area, southwest Idaho, 1992. Open symbols are median dates, which indicate the first date when the number of individuals captured daily had decreased to ca. 50% of the mean for April and continued to decline. Closed symbols are the last date of capture of any individual.

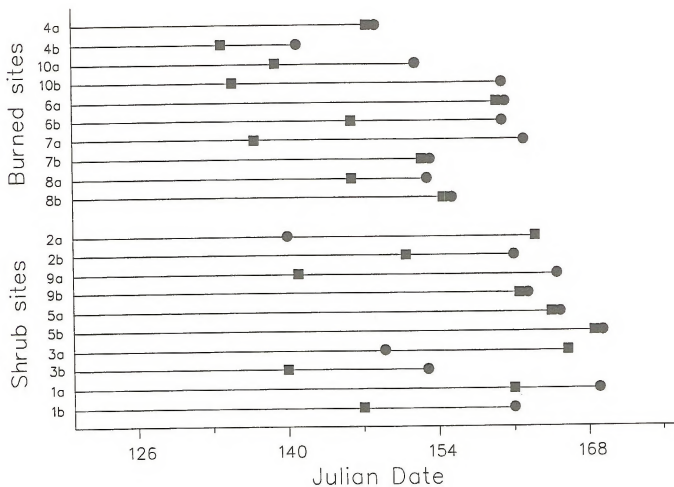


Fig. 4. Timing of emergence of juvenile male (squares) and female (circles) Townsend's ground squirrels on 20 study sites, Snake River Birds of Prey Area, southwest Idaho, 1992. Dates shown are the last date of capture of any individual.

than juvenile males on 11 sites, both sexes were last captured on the same date on 7 sites, and males were captured later than females on 2 sites.

Litter Production.--We classified females that had overwintered at least once as reproductive, based on evidence of lactation (enlarged nipples). The proportion of such females that produced litters in 1992 was generally high on all sites (range 0.84 - 0.98), except on sagebrush Site 5b (0.60). All known-age adults that had overwintered at least twice on burned sites produced litters. On Site 5b the proportion of known-age adults that produced litters was similar to that on other sagebrush sites inside the OTA (Table 8), however, only 47% of the known-age yearlings were reproductive.

Among the necropsied adult females, overall pregnancy rate was 88% (38/43), and average litter size was 8.1 ± 2.1 , similar to rates reported by Smith and Johnson (1985) for SRBOPA Townsend's ground squirrels. Non-reproductive adult females weighed significantly less than reproductively active females (Table 9). This suggests a minimum weight or condition level needed to sustain pregnancy. Smith and Johnson (1985) reported that yearlings tend to be smaller than second-year adults and have lower pregnancy rates, but they did not report weights for pregnant vs. non-pregnant females.

Mass Dynamics

Mean daily masses of squirrels within age and sex categories (Fig. 5) were similar to the patterns reported for 1991 (Fig. 2 in Van Horne et al. 1991) until about day 120 (20 April). At this time the curve representing masses of animals remaining non-torpid

remained flat or declined. Read from the figures, mean masses during late June were approximately 100 g, 50 g, 150 g, and 75 g less than those in 1991 for adult males and females, and juvenile males and females, respectively.

Vegetation

The first axis of the detrended correspondence analysis expressed a gradient from *Bromus tectorum*-dominated habitats to *Ceratoides*-dominated habitats with an eigenvalue of 55.1. The second axis expressed a gradient from *Artemisia*-dominated habitats to *Elymus*-dominated habitats with an eigenvalue of 42.0. In general, site pairs and site types grouped together (Fig. 6), except that site 6a was much more dominated by *Bromus tectorum* during 1992 than were the other burns. We do not know whether this growth of *Bromus tectorum* is a cause or effect, or bears no relation to the abnormally low densities of squirrels on this site during 1991 and 1992.

Structural differences among sites are indicated by shrub height, volume, and density (Table 10). Average heights of shrubs increased among site types in the following order: winterfat < winterfat-sage mosaics < sagebrush inside OTA < sagebrush outside OTA. As expected, heights of shrubs were more variable on the winterfat-sage mosaics than on the other shrub sites, which were dominated by 1 species. The average volume of individual shrubs followed the same pattern among sites as that for shrub height. In contrast, average density of shrubs increased in the order: sagebrush < winterfat-sage mosaic < winterfat. These trends reflect the general negative relationship between shrub height and density among sites. Inter-site

Table 8. Proportions of female^a Townsend's ground squirrels that were reproductive on 15 study sites^b, Snake River Birds of Prey Area, 1992. An individual was classified as reproductive if captured ≥ 1 time with enlarged nipples (evidence of lactation) when most females on that site were reproductive. Sample sizes are in parentheses.

Site	Known-age yearlings	Known-age adults	Unknown	Total ^c
1a				0.84 (13)
3b				0.85 (13)
4a	0.95 (19)	1.00 (5)	0.91 (33)	0.93 (57)
4b	0.87 (15)	1.00 (8)	0.85 (53)	0.87 (76)
5a	1.00 (12)	0.88 (8)	0.85 (13)	0.91 (33)
5b	0.47 (15)	0.83 (12)	0.50 (10)	0.60 (37)
6b	1.00 (8)	1.00 (4)	0.92 (39)	0.94 (51)
7a	0.93 (15)	1.00 (10)	1.00 (10)	0.97 (35)
7b	1.00 (3)	1.00 (3)	0.95 (19)	0.96 (25)
8a	1.00 (7)	1.00 (5)	0.95 (20)	0.97 (32)
8b	1.00 (6)	1.00 (8)	0.94 (17)	0.97 (31)
9a	1.00 (11)	0.83 (6)	1.00 (1)	0.94 (18)
9b	0.80 (15)	1.00 (6)	0.90 (10)	0.87 (31)
10a	0.96 (24)	1.00 (12)	1.00 (20)	0.98 (56)
10b	1.00 (20)	1.00 (13)	0.95 (22)	0.98 (55)

^a Known-age yearlings were born in 1991, known-age adults were born prior to 1991 (≥ 2 years old), and unknown adults were ≥ 1 year old.

^b Sample sizes on 5 sites (1b, 2a, 2b, 3a, 6a) were not adequate to estimate frequency of reproduction.

^c Totals include all classes (yearlings, adults, and unknown).

Table 9. Pregnancy rates and weights of necropsied adult female Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992. Standard deviations in parentheses.

	Pregnant	Non-pregnant
N	38	5
\bar{x} Weight (g)	167 ^b (36) ^a	119 (48) ^a
\bar{x} Scars		
Total	8.1 (2.1)	----
Left Uterine Horn	3.8 (1.9)	----
Right Uterine Horn	4.3 (1.7)	----

^a Significantly different at $P < 0.05$, independent T-test.

^b $N = 34$ for pregnant female weights.

differences in the density and structural characteristics of shrubs probably influences predation risk and behavior of Townsend's ground squirrels. These relationships will be considered in future analyses.

Diet

We collected 117 fecal samples from adults during the first period, 98 samples from adults and 104 samples from juveniles during the second period, and 97 samples from juveniles during the third period.

We do not have results for 1992, but have constructed summaries of the 1991 information (Figs. 7a and 7b). In general, ground squirrels ate *Poa* in a proportion

higher than what is available. Moss was avoided, and *Artemisia* may not be as highly preferred as *Ceratoides*.

Hole Counts

Densities of TOTAL holes were greater on burn sites ($\bar{x} = 381/\text{ha}$, range: 240-500/ha) than on shrub sites ($\bar{x} = 156/\text{ha}$, range: 55-251/ha). The proportion of TOTAL holes classified as ACTIVE was variable among sites (range: 0.14-0.76) and averaged 0.41 ($n = 20$). Observers classified less than half of the holes with high certainty ($\bar{x} = 0.45$, $SD = 0.09$). The number of TOTAL holes per ground squirrel averaged 10 ($SD = 8.6$) on burn sites and 23 ($SD = 21.8$) on shrub sites.

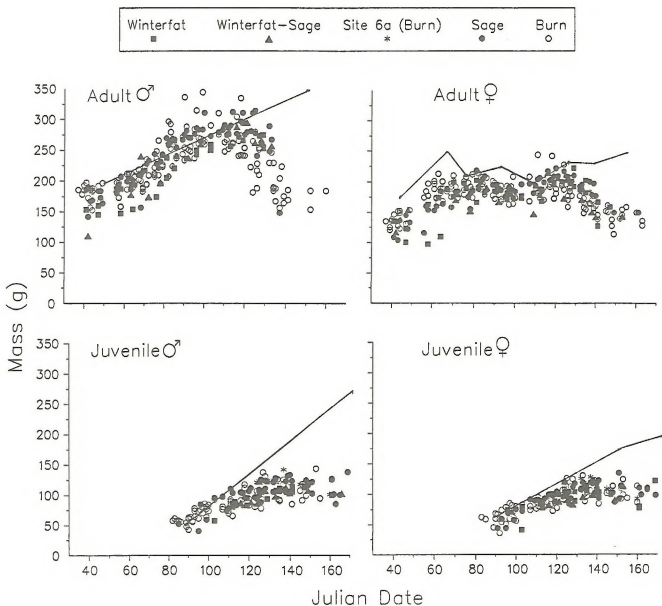


Fig. 5. Mean masses of adult and juvenile Townsend's ground squirrels by sex for each site and date. A curve representing the approximate upper bound for mean weights by date in 1991 (Van Horne et al. 1991, Fig. 2) is superimposed.

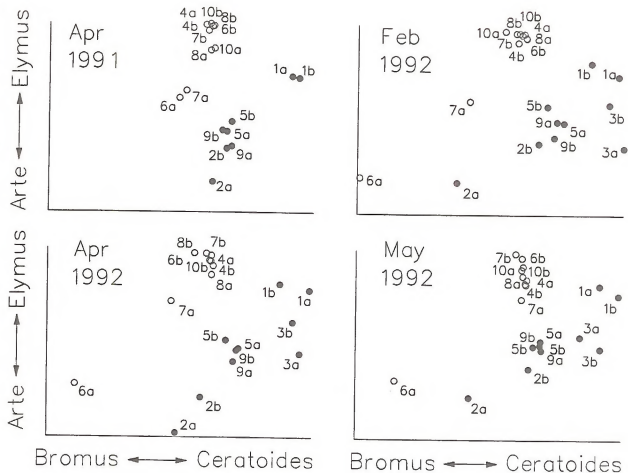


Fig. 6. Ordination of study sites based on percent cover of potential food types using detrended correspondence analysis. Shrub-dominated sites are indicated by solid circles, and burns by open circles.

Table 10. Structural characteristics and density of shrubs on 13 Townsend's ground squirrel study sites^a, Snake River Birds of Prey Area, 19-24 February, 1992.

Site	Height (cm)				Volume (dm ³) ^b			Density (no./m ²)		
	n	\bar{x}	SE	CV(%)	n	\bar{x}	SE	n	\bar{x}	SE
1a	596	16.8	0.28	40.8	595	9.3	0.48	15	5.6	0.26
1b	549	20.2	0.30	34.9	547	12.4	0.53	15	5.2	0.24
2a	102	68.0	3.03	45.0	102	400.2	49.31	15	1.0	0.14
2b	134	58.1	2.81	56.1	134	230.0	31.42	15	1.3	0.21
3a	605	26.9	0.92	83.7	605	75.3	10.58	22	3.9	0.53
3b	412	36.3	1.34	75.1	411	123.6	15.31	22	2.6	0.48
5a	285	32.7	1.07	55.1	285	60.3	5.97	15	2.7	0.23
5b	147	41.0	1.58	46.6	147	108.0	12.46	15	1.4	0.21
8a	13	45.8	6.79	53.4	13	47.3	15.46	15	0.1	0.04
8b	12	39.6	3.85	33.7	12	19.2	7.35	15	0.1	0.06
9a	155	46.8	2.01	53.4	155	160.8	58.91	15	1.5	0.27
9b	178	37.7	1.20	42.6	178	99.0	9.86	15	1.7	0.14
10a	12	17.3	4.40	88.7	12	13.4	11.4	15	0.1	0.09

^a The other 7 sites (4a, 4b, 6a, 6b, 7a, 7b, 10b) had no shrubs.

^b Shrub volume is an index calculated from height (h), maximum radius (a), and the radius perpendicular to the maximum radius (b). Volume = $h(3.1416 \cdot a \cdot b)$.

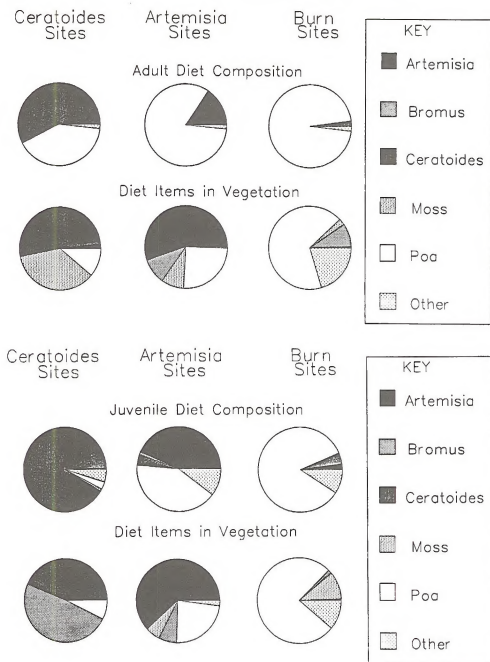


Fig. 7a and 7b. Percent of food items in the diet as indicated by fecal sampling for early-season adults and late-season juveniles in 1991, as compared to the relative percent covers of all plants that occur in the diet, sampled at approximately the same time, with sites combined within *Ceratoides*, *Artemisia*, and burned habitat types.

Squirrel densities were positively correlated with TOTAL, ACTIVE, and POSSIBLY ACTIVE holes (Fig. 8). The relationship was stronger for TOTAL holes than for ACTIVE or POSSIBLY ACTIVE in 1992. However, it is clear that the significance of these relationships is mainly due to the grouping of shrub sites (with low values for hole and ground squirrel densities) separate from burn sites (with high values for hole and ground squirrel densities). Within burn sites, there was no relationship between ground squirrel densities and hole densities (TOTAL: $R_s = -0.19$, $P = 0.60$; ACTIVE: $R_s = -0.53$, $P = 0.12$; POSSIBLY ACTIVE: $R_s = -0.55$, $P = 0.10$). Within shrub sites, ground squirrel densities were not correlated with TOTAL holes ($R_s = 0.42$, $P = 0.23$) and only weakly correlated with ACTIVE holes ($R_s = 0.58$, $P = 0.08$) and POSSIBLY ACTIVE holes ($R_s = 0.59$, $P = 0.07$).

ACTIVE holes were less strongly correlated with ground squirrel densities in 1992 than in 1991 (Fig. 8). However, the relationship in 1991 was mainly due to a strong correlation on shrub sites ($R_s = 0.98$, $P < 0.0001$, $n = 10$). The decreased densities of ACTIVE holes on burn sites in 1992 compared to 1991 (Fig. 8) can be partly explained by the earlier immergence of ground squirrels in 1992, which resulted in little evidence of activity at many holes by early June. We did not count TOTAL holes in 1991, so we can not assess the consistency of TOTAL hole densities between years.

TOTAL holes may be a better index than ACTIVE holes for ground squirrel densities in years such as 1992 when ground squirrels immerge relatively early. Among-year differences in timing of immergence also may have less influence on densities of TOTAL holes than ACTIVE holes, although

we will not be able to test this until future years. Lastly, use of TOTAL holes instead of ACTIVE holes would reduce variability among counts resulting from observer bias in assigning activity classes to holes. Observers classified the activity status of most holes with low certainty.

Our results from 1992 suggest that ground squirrel holes may have a limited usefulness as an index for ground squirrel densities. TOTAL holes could be used to categorize sites as either low or high ground squirrel density (Fig. 8). Sites with hole densities less than ca. 250 per ha were generally sites with low densities of ground squirrels, whereas sites with hole densities greater than ca. 250 were generally sites with high densities of ground squirrels. However, within these 2 categories of hole densities, ground squirrel densities were not strongly associated with hole densities. Our efforts to examine the habitat-specific persistence of holes, and patterns of hole use by ground squirrels, may help to explain the weak relationships we have reported for hole and ground squirrel densities.

Burrow Morphology and Use

The mean greatest distance between entrances in individual burrow systems with 2+ entrances ranged from 0.38 m on OTA sagebrush sites to 1.25 m on winterfat sites. There were no significant differences among sites in either the mean greatest distance between entrances or the mean number of entrances/burrow system (Table 11). This was surprising, as we expected burned sagebrush to have more entrances and longer burrow systems to serve as cover. The number of entrances per burrow system was compared among sites to see if there might be different types of burrow systems, as

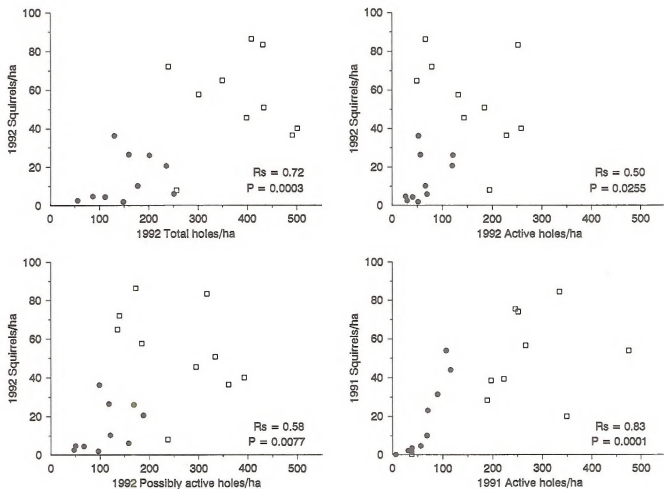


Fig. 8. Densities of Townsend's ground squirrels compared with the total, active, and possibly-active holes in 1992. Densities in 1991 are compared with active holes. Open squares indicate burns, and closed circles indicate shrubby sites.

Table 11. Greatest distance between burrow entrances as determined by hole smoking on 6 site types in the Snake River Birds of Prey Area, 1992. Only burrows with 2+ entrances are included in distance calculations.

Site Type	Greatest Distance Between Entrances (m)					Number of Entrances				
	<i>n</i>	\bar{x}	SE		Range	<i>n</i>	\bar{x}	SE		Range
Burned Sagebrush	10	1.19	0.30	A ^a	0.20-2.90 m	20	1.90	0.29	A	1-6
Winterfat/Sagebrush Mosaic	11	1.19	0.24	A	0.25-2.80 m	20	2.10	0.32	A	1-6
OTA Sagebrush	10	0.38	0.05	A	0.15-0.70 m	20	2.00	0.28	A	1-5
Off OTA Sagebrush	14	0.82	0.15	A	0.23-2.10 m	20	2.25	0.26	A	1-5
Seeded Winterfat	14	1.21	0.35	A	0.20-4.20 m	20	2.50	0.33	A	1-5
Winterfat	13	1.25	0.38	A	0.10-5.20 m	20	2.20	0.28	A	1-5

^a Tukey's Studentized Range Test. Columns with same letter do not differ significantly at alpha = 0.05.

suggested by Alcorn (1940). All sites not dominated by sagebrush had similar distances between burrow entrances, and all sites had a mean of about 2 entrances/burrow system. Sagebrush sites tended to have slightly shorter distances between burrow entrances. Most burrows on all sites had only 1 or 2 entrances (Table 12); only 20-40% of burrows had 3+ entrances (maximum of 6 entrances). Alcorn (1940) reported the characteristics of 14 excavated Townsend's ground squirrel burrows. He grouped them into 3 categories: home burrows of adults, auxiliary burrows at feeding places, and home burrows of young. The latter 2 categories were composed of single-entrance burrows, the auxiliary burrows were the shortest and shallowest, and juvenile home burrows were intermediate in both respects. Reynolds and Wakkinen (1987) reported 2 types of Townsend's ground squirrel burrows: shallow and deep. The shallow burrows were similar in length to Alcorn's juvenile home burrows and similar in depth to his auxiliary burrows. Their deep burrows were similar to Alcorn's home burrows of adults.

Neither study reported the maximum linear distances of burrows, but reported the distance of all main and side tunnels instead. Next season we will excavate several burrow systems to get an idea of what burrows look like below ground when certain patterns occur above ground.

The number of holes used by marked individuals was compared for Sites 4a, 10a, 5b, and 9b. There was little or no information for the remaining sites. Estimates are likely well below the actual number of holes actually used, because hole use by marked individuals could only be determined when individuals were in view.

Ground squirrels on burned sagebrush sites used almost twice the number of holes as those on the OTA sagebrush sites. Site 4a differed significantly from the 2 OTA sagebrush sites (5b, 9b), but none of the others differed significantly (Table 13). Number of holes used differed significantly between the burned sagebrush and OTA sagebrush habitats (Table 13). Ground squirrels on the burned sites probably use burrows for their primary source of cover, whereas those on sagebrush sites have adequate above-ground sources of cover, reducing their dependency on burrows.

The number of marked individuals using each hole differed only for Site 9b (OTA sage; Table 14). This difference is probably due to the use of 3 particular holes. One hole was used by 2 adult females simultaneously with little interaction and no aggression. Another hole was repeatedly used by an adult female and adult male. Finally, on 6 May an adult male and 2 adult females were observed emerging from the same burrow one after the other at approximately 0830 hrs. It is evident that burrow sharing is occurring, although the relationship between those sharing burrows is unknown.

Activity While Above Ground

Type of Activity.--Seventy-nine hrs of recorded behavioral observations were made during the season. Time spent in the observation stand looking for visible ground squirrels was not recorded until 11 March, but 265 hrs were spent in the stand searching for ground squirrels from then until 4 June. Obtaining recorded observations was often difficult on sites with shrub cover; it often took 5 or more hrs in the stand to record 1 hr of data. Only

Table 12. Frequency and percent distributions of burrows with 1 to 6 entrances in each habitat type, Snake River Birds of Prey Area, 1992.

Site Type	Number of Entrances/Burrow System					
	1	2	3	4	5	6
Burned Sagebrush	10 (50%)	6 (30%)	2 (10%)	1 (5%)	0 (0%)	1 (5%)
Winterfat/Sagebrush Mosaic	9 (45%)	6 (30%)	2 (10%)	1 (5%)	1 (5%)	1 (5%)
OTA Sagebrush	9 (45%)	7 (35%)	0 (0%)	3 (15%)	1 (5%)	0 (0%)
Off OTA Sagebrush	6 (30%)	7 (35%)	4 (20%)	2 (10%)	1 (5%)	0 (0%)
Seeded Winterfat	6 (30%)	6 (30%)	4 (20%)	0 (0%)	4 (20%)	0 (0%)
Winterfat	7 (35%)	7 (35%)	2 (10%)	3 (15%)	1 (5%)	0 (0%)

Table 13. Number of holes used by marked Townsend's ground squirrels during behavioral observations, Snake River Birds of Prey Area, 1992, by site, and site type.

Grouping	Number of Holes Used by Marked Individuals			
	<i>n</i>	\bar{x}	SE	
<u>Site</u>				
4a	21	2.2	0.3	A ^a
10a	13	1.6	0.3	AB
5b	14	1.2	0.2	B
9b	16	1.3	0.1	B
<u>Site Type</u>				
Burned Sagebrush	34	2.0	0.3	
Prob. > F = 0.0080				
OTA Sagebrush	30	1.2	0.1	

^a Tukey's Studentized Range Test. Columns with the same letter do not differ significantly at alpha = 0.05.

Table 14. Number of marked Townsend's ground squirrels observed using tagged holes, Snake River Birds of Prey Area, 1992. Sample size is the number of tagged holes and the mean is the number of individuals observing using each hole.

Site	Number of Marked Individuals Per Hole			
	n	\bar{x}	SE	
4a	44	1.1	0.1	B ^a
10a	18	1.2	0.1	B
5b	16	1.1	0.1	B
9b	12	1.7	0.3	A

^a Tukey's Studentized Range Test. Columns with the same letter do not differ significantly at alpha = 0.05.

activities that comprised > 5% of the mean of observation strings across all animals were analyzed. These activities could be grouped into 4 major categories: "In burrow," "walking," "vigilant," and "foraging." "In burrow" was the proportion of time in which ground squirrels were underground during an observation string. "Walking" was the proportion of time spent in locomotion (minus running, which represented < 4% of activity on most sites). "Vigilant" represented the proportion of time in which the ground squirrels were alert and was composed of the time spent sitting on their haunches (not including time spent sitting and eating), standing in the upright picket pin position, and standing on all 4's with their head raised. "Foraging" included eating of any food type.

We believe that observation techniques improved over those of the previous year and may have affected ground squirrel activity less. The use of a 3-m observation stand and a mounted spotting scope for observing ground squirrels instead of a 2-m stepladder and binoculars allowed the observer to watch ground squirrels from a greater distance with less movement (i.e., not having to put down binoculars every 20 sec to record observations). Although vigilance was defined differently this season, time spent in vigilance appeared much lower than last year, and may be due to this change in observation techniques. Information on environmental factors collected simultaneously with behavioral information should allow us to better interpret behaviors. Analysis of this type of data is involved, and will be included in next year's report.

Sex.--Differences within each site were investigated initially to determine if various age or sex classes could be combined. No

significant differences were found between adult males and females for any sites (no adult males observed on sites 1a or 3b; Table 15), therefore adults were combined for overall behavioral analyses.

The lack of significant differences in activity between adult males and females on individual sites was not surprising, as no noticeable difference was seen while watching from the observation stand. We were disappointed in the sample sizes for Sites 1a and 3b, especially the fact that no adult males were observed, very few adult females were observed, and almost no marked juveniles were observed. In the next 2 seasons we will again observe unmarked individuals on these sites if no marked animals are present, especially if the apparent lack of differences in activity patterns between sexes and ages continues to hold. There may be a better opportunity to observe marked animals on these 2 sites if marked animals from this season survive and remain on the sites and additional animals are trapped and marked.

Age.-- Sample sizes for juveniles were generally very small ($n < 8$ of known sex) on all sites, therefore juveniles were grouped together. There were few significant differences between juveniles and adults in the proportion of time spent in various activities. Only Site 5b showed significant differences at an alpha level of 0.0125 (alpha adjusted for multiple comparisons of behaviors using Bonferroni adjustment 0.05/4; Table 16).

The lack of significant differences between the activity patterns of juveniles and adults on almost all the sites (Table 16) was surprising at first, but tends to make sense.

Table 15. Comparisons of percent (%) of time spent in 4 major activities by adult Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992, by site.

Activity	Female			Male			Prob. > F
	n	\bar{x}	SE	n	\bar{x}	SE	
<u>Site 4a</u>							
In Burrow	17	17.3	5.1	12	11.7	3.4	0.4576
Walking	17	11.8	2.4	12	12.2	1.7	0.7508
Vigilant	17	7.2	1.6	12	6.4	0.9	0.9275
Foraging	17	56.1	5.0	12	53.9	4.6	0.8836
<u>Site 10a</u>							
In Burrow	17	14.1	5.7	10	11.0	4.1	0.9243
Walking	17	10.3	1.6	10	8.0	2.9	0.2946
Vigilant	17	7.2	1.6	10	9.4	1.9	0.3258
Foraging	17	56.1	5.0	10	64.0	6.5	0.4060
<u>Site 5b</u>							
In Burrow	14	3.0	1.8	7	1.7	1.1	0.7998
Walking	14	4.2	1.3	7	10.8	4.1	0.2523
Vigilant	14	25.7	7.3	7	24.9	14.0	0.7262
Foraging	14	57.7	8.7	7	56.3	12.5	0.9004
<u>Site 9b</u>							
In Burrow	13	0.6	0.3	8	2.7	2.7	0.6827
Walking	13	10.1	2.4	8	5.8	2.0	0.2432
Vigilant	13	20.5	7.1	8	19.4	9.0	0.9200
Foraging	13	58.3	7.0	8	58.0	11.0	0.9321

Table 16. Comparisons of percent (%) of time spent in 4 major activities between juvenile and adult Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992, by site. Comparisons were made for periods in which both were active (post-juvenile emergence).

Activity	Juvenile			Adult			Prob. > F
	n	\bar{x}	SE	n	\bar{x}	SE	
<u>Site 1a</u>							
In Burrow	17	3.6	2.4	4	12.9	7.5	0.1366
Walking	17	5.3	1.2	4	4.5	3.1	0.8719
Vigilant	17	56.8	8.0	4	57.0	21.7	0.8534
Foraging	17	27.6	5.7	4	16.9	10.5	0.3353
<u>Site 4a</u>							
In Burrow	7	9.1	5.0	26	16.3	3.7	0.2157
Walking	7	16.5	5.7	26	12.8	1.7	0.6402
Vigilant	7	7.9	3.6	26	6.5	1.1	0.8680
Foraging	7	54.2	7.3	26	53.5	3.8	0.8777
<u>Site 10a</u>							
In Burrow	5	9.7	8.5	14	12.0	4.8	0.8050
Walking	5	11.2	3.7	14	11.7	2.4	0.9950
Vigilant	5	8.9	3.8	14	7.4	1.8	0.8559
Foraging	5	61.0	11.7	14	55.2	7.6	0.6892
<u>Site 3b</u>							
In Burrow	10	5.5	3.3	8	4.1	2.1	0.9804
Walking	10	4.8	1.9	8	2.7	1.3	0.5745
Vigilant	10	42.6	10.1	8	77.4	8.0	0.0270
Foraging	10	30.3	10.0	8	13.9	7.5	0.1900
<u>Site 5b</u>							
In Burrow	8	2.1	2.1	11	2.4	2.4	0.9653
Walking	8	2.8	1.4	11	7.4	2.4	0.1222
Vigilant	8	52.1	13.0	11	8.7	3.9	0.0039
Foraging	8	37.9	12.9	11	77.6	4.2	0.0073
<u>Site 9b</u>							
In Burrow	8	5.4	4.2	13	0.2	0.2	0.1241
Walking	8	10.4	3.0	13	9.3	2.1	0.9622
Vigilant	8	20.7	12.5	13	12.5	6.3	0.6399
Foraging	8	59.1	9.2	13	69.3	7.7	0.4345

Juveniles have a non-torpid season of approximately 2 months (Armitage 1981), during which they must grow and acquire sufficient fat stores to survive the estivation/hibernation period. During this period adult females must also gain weight after the lactation period, which is energetically expensive, so they too are able to survive. One might actually expect juveniles to forage more than adults because of the shorter non-torpid season, and all but the 2 OTA sagebrush sites had a slightly (but not significantly) higher mean percent of time spent foraging by juveniles (Table 16). The differences on Site 5b between juveniles and adults is not easily explained. There may be actual differences between ages or the differences may be artifacts of the sampling scheme. If most juveniles observed were ones that had just recently emerged, then vigilance would be expected to be higher, with a resultant decrease in foraging, due to the tendency of juveniles to remain near their natal burrows for 2 or 3 days after immersion.

Habitat.--Because there were few significant differences, adults and juveniles were also grouped together. To determine whether behavior differed among ground squirrels in similar habitat types, all individuals were compared by activity for each site. Site pairs did not differ significantly in the proportion of time spent in each activity (Table 17) and were therefore combined.

When data were combined by site type, the burned sagebrush sites differed from all other site types in all activities except foraging, which did not differ from OTA sagebrush sites (Table 18). Ground squirrels on the burned sagebrush sites were significantly less vigilant than on any of the other sites. We believe that this is due, at

least partially, to the lack of shrub cover and the resultant ability to detect predators, both avian and mammalian, from a further distance than on shrub dominated sites.

The highest vigilance on the winterfat and winterfat/sagebrush mosaic may be related to the winterfat component of each site. P. Sharpe observed that it was often difficult to watch ground squirrels on these 2 sites because winterfat forms a dense cover. It seems that predators, especially mammalian predators and low flying raptors, would be easily hidden from ground squirrels if the ground squirrels were not vigilant. Because winterfat is seldom very tall, ground squirrels could stand upright ("picket pin") to look over most of the shrubs to detect approaching predators. When the mean time spent in the picket pin posture was examined by site type, ground squirrels in winterfat and winterfat/sagebrush habitats used this posture about 22 times and 12 times more often than ground squirrels in the burned sagebrush habitat, respectively (winterfat: $18.2 \pm 3.7\%$ [$n = 23$], winterfat/ sagebrush: $10.4 \pm 4.0\%$ [$n = 18$], burned sagebrush: $0.8 \pm 0.3\%$ [$n = 68$]).

The percent of time spent in the picket pin posture on OTA sagebrush sites ($1.3 \pm 0.5\%$ [$n = 61$]) did not differ significantly from the burned sagebrush sites. It appears that on sagebrush sites there is relatively good visibility of the surrounding area at ground level because of the growth pattern of sagebrush. Although detection of aerial predators in sagebrush is definitely more difficult than on burns, and possibly winterfat sites, ground squirrels are nearly always within a very short distance of cover, while ground squirrels on winterfat sites usually require the use of burrows for any substantial cover. Therefore, ground

Table 17. Comparison of 4 major activities by site for Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992. All squirrels are grouped for each site. Reported values are the percentage (%) of time observed in each activity.

Site	Activity											
	In Burrow				Walking				Vigilant			
	n	\bar{x}	SE		n	\bar{x}	SE		n	\bar{x}	SE	
1a	23	7.0	2.9	AB ^a	23	4.9	1.0	BD	23	58.2	6.9	A
4a	36	13.8	2.8	A	36	12.9	1.7	A	36	7.1	1.0	C
10a	32	12.5	3.5	A	32	9.8	1.3	AB	32	8.4	1.2	C
3b	18	4.8	2.0	AB	18	3.9	1.2	D	18	58.1	7.7	A
5b	29	2.4	1.0	B	29	5.4	1.3	CD	29	32.8	6.3	B
9b	29	2.5	1.4	B	29	9.0	1.4	ABC	29	20.3	5.1	BC

^a Tukey's Studentized Range Test. Column values with same letter do not differ significantly at alpha = 0.05.

Table 18. Comparison by site type of 4 major activities observed in Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992. All squirrels are grouped for each site type and percentage (%) of time spent in each activity is reported.

Site	ACTIVITY											
	In Burrow			Walking			Vigilant			Foraging		
	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE
Burned Sagebrush	68	13.2	2.2 A ^a	68	11.4	1.1 A	68	7.7	0.8 C	68	57.0	2.6 A
Winterfat/Sagebrush Mosaic	18	4.8	2.0 B	18	3.9	1.2 B	18	58.1	7.7 A	18	23.0	6.6 B
OTA Sagebrush	58	2.5	0.9 B	58	7.2	1.0 B	58	26.5	6.9 B	58	55.2	3.9 A
Winterfat	23	7.0	2.9 B	23	4.9	1.0 B	23	58.2	6.9 A	23	23.4	4.8 B

^a Tukey's Studentized Range Test. Column values with same letter do not differ significantly at $\alpha = 0.05$.

squirrels on winterfat or winterfat/sagebrush sites would need to detect predators at a farther distance than those in sagebrush habitat because of the increase in time needed to find cover. This appears to be reflected in the fact that vigilance on the OTA sagebrush sites was less than half that on the winterfat and winterfat/sagebrush mosaics. Lima (1987) examined how vigilance might be affected by various environmental and behavioral factors with a model. He found that the risk of predation depends partially on the distance to cover, the attack rate, and the how quickly a predator attacks. He theorized that vigilance should be highest when predators attack quickly. The speed of attacks would probably be lowest on burned sagebrush sites because of the great distance at which predators can be detected and highest on the winterfat sites if winterfat really does form a good visibility barrier.

The increase in vigilance necessarily detracts from time available for other activities. This is especially evident when looking at the times spent in vigilance and foraging on the winterfat/sagebrush mosaic, OTA sagebrush, and winterfat sites. The time spent in vigilance and foraging on the OTA sagebrush sites is almost perfectly reversed with the same 2 activities on the mosaic and winterfat sites (Table 18). The time spent in a burrow during periods of activity was significantly higher on the burned sagebrush sites than any other sites. This result was expected prior to observations because burrows are nearly the only source of cover available. Also, burrows are generally the only place available for ground squirrels to avoid heat stress on burned sites, while on shrub-dominated sites ground squirrels are able to use the shade underneath shrubs. There appears to be a negative relationship

between the amount of sagebrush present and the amount of time spent in burrows.

We believe that the increase in the time spent walking and the decrease in time spent foraging (although not statistically significant) on the burned sagebrush sites (Table 18) resulted from the early disappearance of *Poa* on these sites. Most grass was dead by mid-April, and there appeared to be little other food available. We would expect an increase in the amount of time spent searching for food and a decrease in actual foraging as foods disappeared. The OTA sagebrush sites showed a large increase in foraging time with a slight increase in walking. These sites tended to have green vegetation available for a longer period, both because sagebrush did not dry out, and because the sagebrush protected some forbs from constant heat. Squirrels on these sites were often observed eating sagebrush and spent a large portion of time later in the season eating burr buttercup (*Ranunculus testicularis*). Next season we will collect forage species for analysis throughout the season to determine the nutritional content of each species and how this varies throughout the season and by site.

Phenology.--When activity was compared between adult males and females for each site by reproductive period (gestation, lactation, and post-lactation) there were few significant differences. No comparisons could be made on Site 4a during gestation because no males were observed during that period. However, during lactation and post-lactation there were no significant differences ($P > 0.264$). On Site 10a, males and females differed only in the time spent walking during post-lactation ($P = 0.040$), while all other differences were not

significant ($P > 0.109$). No observations were recorded on Site 5b during the gestation period, but there were no significant differences during the remaining 2 reproductive periods ($P > 0.1564$). On Site 9b, males and females differed only in the time spent vigilant during gestation and post-lactation ($P = 0.007$ and $P = 0.025$, respectively), while all other differences were not significant ($P > 0.052$). Because there were few significant differences, we believed that it was reasonable to combine the sexes on each site for further analysis.

Only sites representative of the burned sagebrush and OTA sagebrush sites had observations from all reproductive periods, so only these sites were examined. The 2 sites within each of these site types were compared to determine whether the lack of significant differences between site types found for the entire season persisted when the season was divided into reproductive periods. The only significant difference was in the amount of time spent walking during gestation between the 2 burned sagebrush sites ($P = 0.044$). All other comparisons on the burned sagebrush sites had P values greater than 0.1217. There were no significant differences between the OTA sagebrush sites ($P > 0.164$). Even though there were no observations for Site 5b during gestation, we believed that Sites 5b and 9b could be combined because of the lack of differences for all other comparisons. Sites 4a and 10a were also combined, even though there was 1 comparison that was slightly statistically significant.

Within both site types vigilance generally decreased, becoming lowest during post-lactation (Table 19). Foraging increased significantly on OTA sagebrush sites, but

decreased on burned sagebrush sites, although not significantly. Time spent in burrows during observation strings decreased significantly on OTA sagebrush sites, while it increased on burned sagebrush sites, but again not significantly.

We thought that the time spent in burrows might increase during lactation, but this was not necessarily true. On burned sagebrush sites there was an increase, but the increase continued into the post-lactation period (Table 19). On the OTA sagebrush sites, time spent in burrows decreased throughout the season. On burned sites, the increase in time spent in burrows may have been partially caused by increased environmental temperatures. MacWhirter (1991) found that parous female Columbian ground squirrels (*Spermophilus columbianus*) actually spent more time above ground during and following lactation than earlier in the season, similar to the pattern observed on the OTA sagebrush sites. This increased time above ground may allow female ground squirrels to acquire more energy for producing milk. Scan samples (Table 20) show that ground squirrels are above ground about 40% of the day or less. Most lactation may occur during periods of inactivity, and would therefore have little influence on the time spent above ground during periods of activity.

Activity in burned sagebrush and OTA sagebrush sites differed significantly during lactation and post-lactation, but not during gestation (Table 19). Although behavior in burned sagebrush and OTA sagebrush differed significantly for the entire season in all categories except foraging (Table 18), differences were less apparent when compared by reproductive period.

Table 19. Comparison of 4 major activities of Townsend's ground squirrels among the gestation, lactation, and post-lactation periods by site type in the Snake River Birds of Prey Area, 1992.

Activity	PERIOD											
	Gestation				Lactation				Post-Lactation			
	<i>n</i>	\bar{x}	SE		<i>n</i>	\bar{x}	SE		<i>n</i>	\bar{x}	SE	
<u>Burned Sagebrush</u>												
In Burrow	8	5.8	1.0	A ^a	19	12.6	3.4	A	29	17.1	3.8	A
Walking	8	10.2	3.4	AB	19	7.6	1.2	B	29	13.0	1.6	A
Vigilant	8	12.0	2.2	A	19	8.2	1.5	AB	29	5.9	0.9	B
Foraging	8	60.8	5.5	A	19	62.8	4.6	A	29	52.1	4.3	A
<u>OTA Sagebrush</u>												
In Burrow	4	6.9	5.0	A	20	2.7	1.3	AB	18	0.1	0.1	B
Walking	4	3.9	5.0	A	20	6.4	1.7	A	18	9.7	2.0	A
Vigilant	4	26.2	11.2	AB	20	32.8	6.9	A	18	10.9	4.7	B
Foraging	4	44.6	8.2	AB	20	45.7	6.6	B	18	73.9	5.5	A

^a Tukey's Studentized Range Test. Row values with same letter do not differ significantly at $\alpha = 0.05$.

Table 20. Percent of time Townsend's ground squirrels were above ground in a burned sagebrush habitat during the daylight hours as estimated from scan sampling.

Period	Percent of Time Spent Above Ground			
	<i>n</i>	\bar{x}	SE	
February	6	38.8	8.0	A ^a
March	27	32.4	4.0	A
April	58	24.2	1.5	A
May	33	15.3	1.6	B

^a Tukey's Studentized Range Test. Column values with same letter do not differ significantly at $\alpha = 0.05$.

Time Above Ground.--Scan samples were only summarized for Sites 4a and 10a (burned sagebrush) for determining the proportion of overall activity because ground squirrels on other sites were easily obstructed from sight by shrubs and brush, even when near the observation stand. Ground squirrels on the burned sites were usually visible up to 75 m or more. All animals from Sites 4a and 10a were combined after an ANOVA with multiple effects indicated no significant differences between sites, ages, or sexes. The season from February through May was broken down by month to look at changes in activity. Estimated time spent above ground ranged from a high of $38.8 \pm 8.0\%$ in February to a low of $15.3 \pm 1.6\%$ in May with a steady decline across all 4 months (Table 20).

We think scan sampling is a good index of overall daily activity, but it is only adequate on burned sites with good visibility. Even then, the predicted proportion of time spent above ground is probably slightly lower than the actual time due to animals moving in and out of the viewing area or being missed in a scan for another reason. Nonetheless, ground squirrels on burned sagebrush sites showed a steady decline in overall activity as the season progressed, although only May was significantly lower (Table 20). Early in the season ground squirrels were observed above ground > 2 hr without going into burrows at all, but later they went into burrows for short periods several times during a 30-min observation period, probably to avoid high temperatures and radiation. It is difficult to determine whether ground squirrels on shrub-dominated sites exhibit

similar patterns of behavior as those on burned sites. Time spent above ground may be similar, but we don't think ground squirrels on shrub sites spend as much time in burrows, even when inactive. During observations in the warmer part of the season on the sagebrush and winterfat/sagebrush sites ground squirrels were often spotted lying under sagebrush in the shade, often with a thin layer of dirt on them which they got by plowing forward slightly through the topsoil. This may be as or more effective than cooling off in a burrow, especially if there is a breeze.

Predation.-- Predation pressure by raptors did not vary significantly among sites (Table 21). The highest estimated predation pressure was on Site 4a (burned sagebrush),

but this was only 0.12 raptors/15 min or 1 raptor approximately every 2.1 hrs.

Next season we plan to investigate the ability of ground squirrels to detect predators on various sites. This could be accomplished by mounting small fish-eye mirrors at heights representing ground squirrels in different postures (i.e., standing, sitting, picket pin) and measuring the distance to which an approaching object of different heights is first detected when looking in the mirrors. Approaching objects could represent anything from a snake (2-3 cm high) to a low flying raptor (3-4 m high). This experiment would be simple, require little time (1-2 days), and may give some insight into possible reasons for the differences in behavior and predation risk among habitats.

Table 21. Number of raptors observed on or near Townsend's ground squirrel sites during 15-min scan samples in the Snake River Birds of Prey Area, 1992.

Site	Percent of Time Spent Above Ground			
	n	\bar{x}	SE	
1a	91	0.08	0.04	A ^b
4a	52	0.12	0.08	A
10a	52	0.04	0.03	A
3b	49	0.06	0.03	A
5b	65	0.06	0.03	A
9b	80	0.09	0.03	A

^a Tukey's Studentized Range Test. Column values with same letter do not differ significantly at $\alpha = 0.05$.

Average time spent vigilant did not differ between males and females during any of the reproductive periods. Loughry and McDonough (1989) had similar results for the California ground squirrel (*Spermophilus beecheyi*). We expected vigilance to be greatest after the juveniles had emerged (post lactation, Table 19), but it was actually lowest during this period. Loughry and McDonough (1989) found that vigilance did not vary before and after pup emergence. One possible reason for our observed decrease in vigilance is that much of the initial vigilance decreased as ground squirrels became accustomed to the observer. Decreased vigilance could also be a trade-off for increased foraging and search time.

Bechard (1982) reported that vegetative cover was more important than prey density in the selection of hunting sites by Swainson's hawks (*Buteo swainsonii*). Similarly, Wakely (1978) found that ferruginous hawks (*Buteo regalis*) hunted in areas of bare ground and pasture more than would be expected by chance, and Toland (1987) found that American kestrels (*Falco sparverius*) were attracted to disturbed areas with low vegetation. We would expect raptors to be more common over burned sites and probably winterfat sites because of the low vegetation, but the number of raptors observed over our observation sites did not differ significantly (Table 21). The species of those raptors observed was not recorded, so different raptors may prefer different habitats. Northern harriers (*Circus cyaneus*) were rarely observed over burned sites. Most often they were seen flying low over sagebrush and winterfat sites, where they are able to use their ability to sneak up on prey as described by Dunne et al. (1988). Next season we will try to identify raptors

observed over sites to determine which raptors prefer which habitat types, and coordinate our findings with results of Study 1.

Ground squirrels reacted differently to raptors in different habitats. Alarm calls were seldom heard when a raptor was flying over burned sagebrush areas. Squirrels would generally freeze if the raptor was high above the ground and run silently towards a burrow if it was flying low or swooping down. P. Sharpe was able to tell when a raptor was low over the site by the scattering of ground squirrels. In contrast, on shrub-dominated sites there was often a 2-note alarm call to low flying raptors, usually northern harriers. P. Sharpe could immediately locate the raptor by looking towards the location of the alarm call. There was little response to high flying raptors. We do not know whether the 2-note call is in response to being startled by the raptor or a warning to other ground squirrels in the area. If it is an alarm call, ground squirrels may have different alarm calls for raptors and other earthbound predators, because calls made in response to humans walking across sites are usually 4+ notes.

Cannibalism, Infanticide, Scavenging and Interspecific Aggression.--Alcorn (1940) reported that ground squirrels in Nevada appeared to be concentrated along the agricultural fields. Similar behavior was noted by our field crews in the SRBOPA in 1992. Alcorn also described ground squirrels as eating members of their own species that had been killed by cars. We often observed this while traveling along paved roads, with ground squirrels often trying to pull larger animals, such as jackrabbits off the road.

We did not observe any infanticide, but we did see juveniles being eaten by conspecifics on the study sites. Several times during the season partially-eaten juveniles were found by burrow entrances. Predation on other species also seems to occur. On 13 February an unmarked Townsend's ground squirrel was observed fighting with an Ord's kangaroo rat (*Dipodomys ordii*) on Site 4a. The ground squirrel killed the kangaroo rat, dragged it about 15 m to some shrub cover and partially ate the kangaroo rat's face. Other ground squirrels were observed capturing and eating invertebrates, but no other predation on other vertebrates was observed.

Fat Analysis

Survival.--At least 24 of 55 juvenile ground squirrels from 4 sites (1a and b, 4a and b) with known mass and body composition in June 1991 survived the dormant season. Overwinter survival was not predicted by the amount of fat stored relative to lean mass (Fig. 9), or by any other measure of condition (mass, % fat; Table 22). The only significant difference between survivors and those whose fate was unknown was in mass. Mass varied with sex ($F = 4.539$; $df = 1,47$; $P = 0.037$); surviving females tended to be smaller than females whose fate was not known, but surviving males were larger than males of unknown fate (Table 22).

Sex.--Males were significantly larger and had significantly greater lean mass than females in February. Habitat type was not significantly related to mass and body composition overall or by sex (Table 23), although females tended to be smaller ($P = 0.195$), with less lean mass ($P = 0.096$), more fat ($P = 0.118$), and higher fat indexes ($P = 0.131$) on shrub-covered sites than on

burned sites. On 2 of 4 shrub sites (1b and 5a), males were larger with more lean mass (P 's = 0.017-0.052) than females. On 2 of 3 burned sites (4a and 8a), males were larger than females with more lean mass (P 's = 0.019-0.043), but females also tended to have a greater percent fat ($P = 0.060$) and had larger indexes of condition ($P = 0.031$) on Site 4a than males (Table 23).

Habitat and Phenology.--Time spent above ground by adults declined during May sampling, particularly on shrub sites (Table 20). Overall, ground squirrels from shrub sites did not differ significantly in any measure of body condition between sexes within a given age class. Adults of both sexes had a greater percent body fat than juveniles ($P < 0.0005$), and adult females had more lean mass ($P = 0.023$) and higher fat indexes (P 's < 0.0005) than juvenile females. Individual sites and site types followed this general pattern, except that juvenile males were larger than juvenile females on Site 1b ($P = 0.020$).

In contrast to shrub sites, males of both age classes on burned sites were larger than females (juvenile $P = 0.014$, adult $P = 0.002$), with significantly more lean mass (juvenile $P = 0.014$) and percent fat (adult $P = 0.002$) than females in their respective age classes. As on shrub sites, adults in each age class were larger and had more lean mass, percent fat, and higher indexes of body condition than juveniles (all P 's < 0.0005). On burned sagebrush sites, few juveniles were captured, and these were similar in mass and body composition. On burned reseeded sites juvenile males were bigger than females ($P = 0.001$), but on Site 8b juvenile females had larger indexes of condition ($P = 0.003$) because each sex class had similar percent body fat (Table 24). In

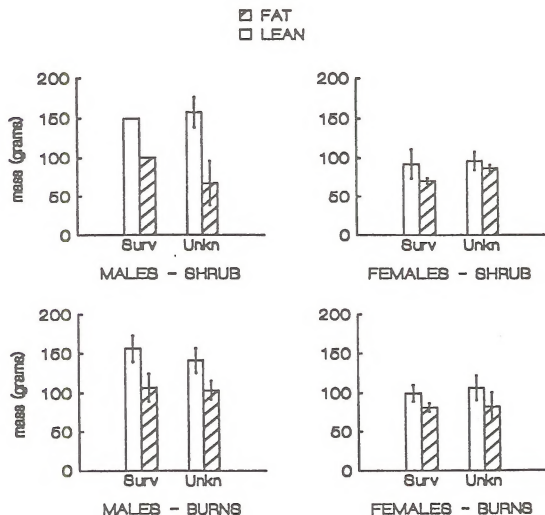


Fig. 9. Variation in body composition of Townsend's ground squirrels for survivors through hibernation (Surv) and those whose fate is not known (Unkn) from shrub sites (1a, 1b), and a burn (4a) through winter 1991-1992.

Table 22. Average mass and body composition of juvenile male (M) and female (F) Townsend's ground squirrels with different fates. Standard deviations in parentheses. Winterfat sites are 1a and 1b, and the burned sage is site 4a.

	<i>n</i>	Total Mass (g)	Lean Mass (g)	% Fat	Index ^a
SURVIVORS					
<u>Winterfat</u>					
Male	1	250.0	144.5	40.2	0.269
Female	2	162.5 (10.6)	92.3 (13.3)	43.4 (4.5)	0.479 (0.117)
<u>Burned Sage</u>					
Male	8	262.6 (33.6)	156.1 (23.3)	40.5 (6.2)	0.268 (0.075)
Female	13	180.6 (15.5)	99.5 (18.9)	45.3 (6.7)	0.481 (0.153)
FATE UNKNOWN					
<u>Winterfat</u>					
Male	5	225.0 (34.4)	157.5 (20.9)	29.1 (10.9)	0.190 (0.094)
Female	4	182.8 (15.1)	96.0 (11.5)	47.6 (2.0)	0.503 (0.079)
<u>Burned Sage</u>					
Male	13	244.3 (20.4)	141.1 (28.1)	42.4 (9.1)	0.328 (0.157)
Female	9	188.7 (11.8)	106.3 (23.4)	43.4 (13.8)	0.441 (0.171)

^a % fat/gm lean mass

Table 23. Mean total and lean mass and body composition of adult Townsend's ground squirrels on the Snake River Birds of Prey Area soon after emergence from hibernation, February 1992. Standard deviations in parentheses.

Site Type	Site No.	Sex	n	Total Mass (g)	Lean Mass (g)	% Fat	Index (% fat/gm lean)
Winterfat	1a	M	2	153.5 (37.5)	99.0 (20.4)	35.2 (2.5)	0.361 (0.049)
		F	1	135.0	103.4	31.6	0.23
	1b	M	2	165.5 (9.2)	137.9 (35.2)	17.1 (16.7)	0.145 (0.158)
		F	3	99.7 (19.7)	60.8 (9.8)	38.6 (3.5)	0.642 (0.072)
	all	M	4	159.5 (23.3)	118.4 (32.5)	26.2 (14.3)	0.253 (0.157)
		F	4	108.5 (23.9)	71.5 (22.8)	34.8 (8.1)	0.538 (0.216)
Sage	5a	M	4	181.0 (13.5)	144.3 (13.3)	20.3 (3.8)	0.143 (0.036)
		F	3	121.7 (22.7)	98.4 (22.8)	19.5 (4.1)	0.209 (0.076)
	5b	M	5	150.2 (32.8)	111.3 (33.8)	27.0 (9.6)	0.289 (0.192)
		F	5	131.6 (31.6)	97.3 (23.2)	26.0 (2.7)	0.281 (0.082)
	all	M	9	163.9 (29.5)	126.0 (30.7)	24.0 (8.0)	0.224 (0.158)
		F	8	127.9 (27.3)	97.8 (21.4)	23.6 (4.5)	0.254 (0.083)
	Shrub Sites all	M	13	162.5 (26.8)	123.7 (30.1)	24.7 (9.7)	0.233 (0.152)
		F	12	121.4 (26.8)	89.0 (24.5)	27.3 (7.8)	0.349 (0.191)

Table 23. Continued.

Site Type	Site No.	Sex	n	Total Mass (g)	Lean Mass (g)	% Fat	Index (% fat/gm lean)
Burned Sage	4a	M	4	157.0 (10.9)	137.0 (7.0)	12.6 (4.7)	0.092 (0.036)
		F	6	151.3 (11.5)	122.2 (11.1)	19.3 (3.8)	0.160 (0.044)
Burned Reseeded	8a	M	10	171.7 (23.6)	133.0 (30.0)	23.8 (12.7)	0.205 (0.143)
		F	4	131.0 (21.2)	92.8 (25.8)	30.1 (8.9)	0.363 (0.199)
	8b	M	6	149.5 (26.3)	109.3 (25.9)	27.7 (6.6)	0.286 (0.169)
		F	10	124.9 (26.5)	98.4 (25.3)	21.7 (7.8)	0.252 (0.151)
	all	M	16	163.4 (26.2)	124.1 (30.1)	25.2 (10.7)	0.236 (0.153)
		F	14	126.6 (24.5)	96.8 (24.6)	24.1 (8.7)	0.284 (0.166)
Burned Sites	all	M	20	162.1 (23.8)	126.7 (27.4)	22.7 (11.0)	0.207 (0.149)
		F	20	134.0 (24.1)	104.4 (24.2)	22.7 (7.8)	0.247 (0.151)
All Sites	all	M	33	162.3 (24.6)	125.5 (28.0)	23.5 (10.4)	0.217 (0.148)
		F	32	129.3 (25.5)	98.7 (25.1)	24.4 (8.0)	0.285 (0.172)

Table 24. Average mass and body composition of Townsend's ground squirrels in the Snake River Birds of Prey Area, May, 1992, prior to estivation. Standard deviations in parentheses.

Site Type	Site No.	Age	Sex	n	Mass (g)	Lean (g)	% Fat	Index (% fat/gm lean)
Winterfat	1a	J	M	3	109 (10.6)	86.8 (12.3)	20.6 (3.4)	0.243 (0.070)
			F	7	119.7 (20.3)	92.5 (11.1)	21.8 (8.1)	0.234 (0.083)
		A	F	1	200.0	103.4	48.3	0.467
	1b	J	M	6	110.7 (8.7)	79.3 (9.6)	28.3 (6.5)	0.368 (0.123)
			F	7	98.9 (5.7)	74.1 (7.0)	25.0 (5.0)	0.343 (0.092)
		A	F	1	156.0	80.3	48.5	0.605
Winterfat	all	J	M	9	110.1 (8.7)	81.8 (10.5)	25.7 (6.7)	0.326 (0.121)
			F	14	109.3 (18.0)	83.3 (13.0)	23.4 (6.7)	0.288 (0.102)
		A	F	2	178.0 (31.1)	91.8 (16.4)	48.4 (0.2)	0.536 (0.097)
Sage	5a	J	M	9	105 (25.0)	74.1 (12.6)	28.2 (6.8)	0.383 (0.081)
			F	11	97.7 (23.9)	72.5 (13.3)	24.0 (11.2)	0.338 (0.181)
		A	F	2	169.5 (9.2)	87.3 (5.7)	48.5 (0.6)	0.557 (0.043)
	5b	J	M	10	112.3 (21.3)	74.3 (12.1)	33.2 (6.3)	0.457 (0.104)
			F	11	119.5 (13.6)	81.3 (7.7)	31.6 (5.9)	0.392 (0.086)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
Sage	all	J	M	19	108.8 (22.8)	74.2 (12.0)	30.8 (6.9)	0.422 (0.099)
			F	22	108.6 (22.0)	76.9 (11.5)	27.8 (9.6)	0.365 (0.141)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
	all	J	M	19	108.8 (22.8)	74.2 (12.0)	30.8 (6.9)	0.422 (0.099)
			F	22	108.6 (22.0)	76.9 (11.5)	27.8 (9.6)	0.365 (0.141)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
All Shrub	all	J	M	28	109.2 (19.2)	76.6 (11.9)	29.2 (7.1)	0.391 (0.114)
			F	36	108.9 (20.3)	79.4 (12.3)	26.1 (8.7)	0.335 (0.131)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
	all	J	M	28	109.2 (19.2)	76.6 (11.9)	29.2 (7.1)	0.391 (0.114)
			F	36	108.9 (20.3)	79.4 (12.3)	26.1 (8.7)	0.335 (0.131)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
All Shrub	all	J	M	28	109.2 (19.2)	76.6 (11.9)	29.2 (7.1)	0.391 (0.114)
			F	36	108.9 (20.3)	79.4 (12.3)	26.1 (8.7)	0.335 (0.131)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)
	all	J	M	28	109.2 (19.2)	76.6 (11.9)	29.2 (7.1)	0.391 (0.114)
			F	36	108.9 (20.3)	79.4 (12.3)	26.1 (8.7)	0.335 (0.131)
		A	M	3	214.0 (58.9)	108.8 (27.0)	48.9 (1.8)	0.469 (0.117)

Table 24. Continued.

Site Type	Site No.	Age	Sex	n	Mass (g)	Lean (g)	% Fat	Index (% fat/gm lean)
Burned Sage	4a	J	M	2	85.0 (14.1)	66.1 (7.3)	21.9 (4.4)	0.330 (0.029)
			F	3	94.0 (16.4)	72.1 (8.8)	22.8 (4.4)	0.315 (0.026)
		A	M	1	184.0	88.9	51.7	0.581
			F	5	138.6 (9.9)	74.8 (10.9)	46.1 (5.8)	0.634 (0.157)
	4b	J	M	2	127.5 (3.5)	87.7 (6.4)	31.1 (6.9)	0.359 (0.105)
			F	1	87.0	61.1	29.7	0.486
		A	M	5	190.0 (17.9)	94.4 (15.2)	50.4 (5.1)	0.551 (0.131)
			F	11	163.9 (20.0)	90.6 (14.5)	44.6 (7.2)	0.510 (0.136)
	all	J	M	4	106.2 (25.9)	76.9 (13.7)	26.5 (7.1)	0.344 (0.065)
			F	4	92.2 (13.8)	69.3 (9.1)	24.6 (5.0)	0.358 (0.088)
		A	M	6	189.0 (16.2)	93.5 (13.8)	50.6 (4.6)	0.556 (0.118)
			F	16	156.0 (20.9)	85.6 (15.1)	45.1 (6.6)	0.549 (0.149)
Burned Reseeded	8a	J	M	5	118.8 (11.0)	87.6 (7.5)	26.0 (6.0)	0.300 (0.085)
			F	7	110.3 (16.9)	82.9 (12.3)	24.6 (6.0)	0.305 (0.092)
		A	F	7	173.3 (16.3)	96.0 (14.2)	44.6 (6.9)	0.483 (0.152)
			8b	J	M	4	120.8 (6.2)	95.5 (6.5)
	F	15			98.9 (15.4)	75.3 (10.2)	23.3 (5.6)	0.312 (0.076)
	A	M		2	222.0 (0)	89.0 (1.4)	59.9 (0.6)	0.674 (0.017)
		F		12	166.1 (8.9)	96.9 (9.3)	41.7 (4.4)	0.437 (0.083)
	all	J	M	9	119.7 (8.7)	91.1 (7.8)	23.8 (5.1)	0.285 (0.078)
			F	22	102.5 (16.4)	77.7 (11.2)	23.7 (5.6)	0.310 (0.079)
		A	M	2	222.0 (0)	89.0 (1.4)	59.9 (0.6)	0.674 (0.017)
			F	19	168.7 (12.2)	96.8 (11.0)	42.7 (5.4)	0.454 (0.112)
	All Burned Sites	J	M	13	115.5 (16.1)	86.7 (11.6)	24.6 (5.8)	0.289 (0.080)
F				26	100.9 (16.2)	76.4 (11.2)	23.9 (5.4)	0.317 (0.018)
A			M	8	197.2 (20.5)	92.4 (11.9)	53.0 (5.8)	0.585 (0.114)
			F	35	162.9 (17.7)	91.6 (14.0)	43.8 (6.0)	0.497 (0.137)

other respects, individual sites and site types followed the general patterns observed on burned sites.

Comparisons were made between site pairs and between shrub and burned sites for each sex and age class (Table 24). Adult males were only captured on burned sites; they were larger ($P = 0.034$), with more fat ($P = 0.002$) on the burned, reseeded sites than on the burned sites in the OTA. Adult females on winterfat sites were bigger ($P = 0.055$) and fatter ($P = 0.036$) than those on the burned sites in the OTA, but were similar in size and body composition to those on sagebrush sites and on the burned, reseeded sites. Adult females on the burned reseeded sites were bigger ($P = 0.028$) and had greater lean mass ($P = 0.046$) than those on the burned sites inside the OTA. Fat mass did not vary between sites, but obviously was a smaller percentage of total body mass on the burned, reseeded sites (Table 24).

Neither juvenile males nor juvenile females differed in size, lean mass, or fat between burn site types (burns in the OTA vs. burned, reseeded sites) or between shrub site

types (winterfat vs. sage). Nor did juvenile females differ in any parameter between burn sites and shrub sites. Juvenile males, however, had greater lean mass ($P = 0.009$) on burn sites than on shrub sites.

Ground squirrels captured in consecutive weeks in May lost weight between captures (Table 25); most recaptures were females; there were no significant site-specific differences in patterns of weight and body composition changes between adult and juvenile females. Significance values for changes in total mass, lean mass, fat mass, and percent fat, respectively, were 0.625, 0.767, 0.191, and 0.572 on Site 8a; and 0.129, 0.356, 0.090, and 0.990 on Site 8b. On Sites 8a and 8b, mass loss was significantly related to loss of lean mass (Site 8a: $P = 0.016$; Site 8b: $P = 0.001$), but not to changes in fat or percent fat (Table 25). Sample size of recaptures was small on Site 4a; the measured mass loss was not related significantly to any other change in body composition. The trend on this site appeared to be opposite that measured on Sites 8a and b, however, with average mass loss equal to loss of fat.

Table 25. Average change in mass and body composition of individual Townsend's ground squirrels in the Snake River Birds of Prey Area captured in consecutive trapping sessions during May, 1992. Standard deviations in parentheses.

Site	n	Δ Total Mass (g)	Δ Lean Mass (g)	Δ Fat (g)	Δ %Fat
4a	3	-9.0 (12.0)	-0.1 (9.0)	-8.9 (4.5)	-4.6 (2.0)
8a	5	-6.2 (5.4)	-15.3 (4.9)	+9.1 (1.8)	+9.0 (2.3)
8b	10	-8.2 (16.5)	-4.5 (13.9)	-3.7 (8.2)	+0.3 (5.5)

The mass and body composition of ground squirrels captured 1 week later was compared to that of animals not recaptured. There were no significant differences between the 2 groups in any parameter. On Site 8b, P-values for total mass, lean mass, and percent fat for juvenile females were 0.371, 0.161, and 0.387, respectively. On Site 4a the P-values for adult females were 0.599 for total mass, 0.799 for lean mass, and 0.570 for percent fat. On Site 8a the P-values for adult females were 0.452 for total mass, 0.695 for lean mass, and 0.143 for percent fat.

Initial results indicate that body composition affects survival differently for juvenile males and females and for ground squirrels on different site types. It appears that, over mild winters, survival favors smaller lean mass for females on both shrub-covered and burned sites, and for males on shrub sites. This is supported by February assessments of body composition and condition, when males were larger than females on all sites. Females on shrub sites tended to be smaller but in better condition than females on burned sites, and females were in better condition than males on burned sites. Body composition among site types appears to follow similar patterns in drought. Males were bigger than females in each age class on burned sites but not on shrub sites. Few juveniles were captured on some burned sites, and males were heavier than females at the expense of fat on other burn sites. These patterns suggest that larger animals occur on burn sites, regardless of available food. Perhaps the cooler winter temperatures on sites without shrub cover (J. Munger, Boise State University, pers. commun.) allow larger animals to survive dormancy more readily with smaller relative fat stores.

When there is insufficient food available late in the fattening phase, ground squirrels on burn sites appeared to either rid themselves of some of this excess lean mass, or defend the stores of fat they have sequestered. That ground squirrels on the burned sagebrush site lost fat rather than lean mass suggests either that they are as small as they can get, or that their smaller relative size is amply supported with the fat stored prior to food limitation. Townsend's ground squirrels in the laboratory lost fat and lean mass when fasted in summer (Corn and Van Horne 1991), supporting the latter hypothesis to some extent. The larger sample size of individuals to follow through the 1992-1993 winter will allow us to examine these trends more rigorously.

Laboratory Animals.--Fatty acid composition of adipose tissue sampled from wild and laboratory ground squirrels differed significantly (Table 26). Laboratory animals had more animal-produced FA's (16:0, 16:1, 18:0, and 18:1), especially 18:0's, and fewer 18:3 FA's that must be provided in the diet. The lack of a large pool of 18:3 FA did not prevent laboratory animals from becoming torpid in early May. FA composition of wild ground squirrels varies among site types (Table 27). Wild ground squirrels with fewer 18:3 FA's had more animal-produced 18:1 and 16:0 FA's and more dietary 18:2 FA's.

Experimental manipulation of dietary FA's resulted in significant differences in adipose tissue FA composition of ground squirrels on different diets (Table 28). Animals fed the diet high in polyunsaturated FA's had more 18:2 FA's ($P = 0.004$) than those on the

Table 26. Fatty acid (FA) composition (% of total Fas) of adipose tissue sampled in April and May, 1992, from Townsend's ground squirrels on the Snake River Birds of Prey Area or those held at least 2 months in the lab. Standard deviations in parentheses.

FA ^a	SRBOPA (%)		Lab (%)		P
N	18		25		
16:0	13.0	(2.8)	16.0	(1.2)	<0.0005
16:1	2.3	(1.5)	7.4	(1.9)	<0.0005
18:0	2.4	(3.9)	26.1	(9.5) ^b	<0.0005
18:1	32.8	(9.4)	27.3	(9.2) ^b	0.100
18:0 + 18:1	35.3	(9.6)	53.3	(3.8)	<0.0005
18:2	17.6	(4.1)	17.4	(3.2)	0.860
18:3	26.4	(14.6)	2.2	(3.0)	<0.0005

^a Fatty acid classes are denoted by the number of carbons in the carbon chain and the number of double bonds between carbons.

^b Some GC (gas chromatography) assays did not result in a clear separation of peaks between 18:0 and 18:1 Fas. For comparisons of these classes, N of lab animals is 15.

Table 27. Fatty acid composition (% of total fatty acids) of adipose tissue of Townsend's ground squirrels from the Snake River Birds of Prey Area in May 1992. Standard errors in parentheses.

Fatty Acid	Site Types				Signif. ^b
	Winterfat <i>n</i> = 8	Sage <i>n</i> = 9	Burned Sage <i>n</i> = 9 ^a	Burned Reseeded <i>n</i> = 9 ^a	
10:0	0.05 (0.05)	0.02 (0.01)	0.13 (0.12)	0.19 (0.15)	n.s.
12:0	0.37 (0.17)	0.45 (0.09)	0.55 (0.16)	1.01 (0.26)	n.s.
14:0	0.86 (0.21)	0.17 (0.07)	0.33 (0.13)	0.51 (0.21)	W>S (<i>P</i> =0.020)
14:1	0.05 (0.04)	0.07 (0.03)	0.20 (0.11)	0.10 (0.05)	n.s.
16:0	14.01 (2.30)	10.22 (0.56)	15.00 (0.49)	13.10 (0.88)	B>S (<i>P</i> =0.023)
16:1	1.97 (0.16)	1.46 (0.13)	2.18 (0.14)	3.69 (0.87)	BR>W (<i>P</i> =0.046)
					BR>S (<i>P</i> =0.005)
17:0	0.46 (0.08)	0.29 (0.14)	0.32 (0.03)	0.23 (0.06)	n.s.
17:1	0.37 (0.09)	0.12 (0.04)	0.45 (0.03)	0.23 (0.09)	W>S (<i>P</i> =0.045)
					B>S (<i>P</i> =0.004)
18:0	2.09 (0.18)	1.40 (0.17)	1.52 (0.02)	3.46 (2.21)	n.s.
18:1	36.64 (1.79)	22.30 (1.56)	40.52 (1.59)	32.55 (4.12)	W>S (<i>P</i> =0.001)
					B>S (<i>P</i> <0.0005)
					BR>S (<i>P</i> =0.018)
18:0 and 18:1	39.39 (1.95)	22.86 (2.47)	42.80 (3.51)	36.29 (10.93)	W>S (<i>P</i> =0.022)
					B>S (<i>P</i> =0.012)
18:2	22.74 (1.36)	12.95 (0.84)	19.38 (1.80)	19.40 (1.43)	W>S (<i>P</i> <0.0005)
					B>S (<i>P</i> =0.008)
					BR>S (<i>P</i> =0.008)
18:3	14.04 (3.50)	45.19 (2.75)	15.22 (1.15)	22.37 (5.52)	W<S, B<S, BR<S (all <i>P</i> <0.0005)
20:0	0.53 (0.09)	1.00 (0.11)	0.52 (0.09)	0.35 (0.10)	S>W (<i>P</i> =0.006)
					S>B (<i>P</i> =0.004)
					S>BR (<i>P</i> <0.0005)
20:1	0.13 (0.14)	1.70 (0.27)	0.06 (0.04)	0.30 (0.17)	S>W, S>B, S>BR (all <i>P</i> <0.0005)
					S>B (<i>P</i> =0.003)
20:3	0.23 (0.06)	0.47 (0.11)	0.10 (0.03)	0.23 (0.07)	n.s.
20:4	0.51 (0.14)	0.32 (0.08)	0.37 (0.05)	0.32 (0.10)	n.s.
20:5	0.34 (0.02)	0.13 (0.04)	0.22 (0.16)	0.09 (0.04)	n.s.
22:6	1.42 (1.04)	0.15 (0.07)	0.11 (0.04)	0.06 (0.03)	n.s.

^a For 18:0 and 18:1 fatty acids, *n* = 7 for burned sage, and *n* = 8 for burned reseeded.

^b Tukey's HSD; W = winterfat, S = sage, B = burned sage, and BR = burned reseeded.

Table 28. Fatty acid composition of subcutaneous adipose tissue of captive Townsend's ground squirrels fed diets high or low in PUFAs, or maintained on laboratory rat chow. Standard errors in parentheses.

Fatty Acid	High PUFA diet (n = 2)		Low PUFA diet (n = 3)		Rat Chow diet (n=24)		t ^a	P ^a
10:0	0	(0)	0.033	(0.034)	0.016	(0.003)	-	-
12:0	0.405	(0.405)	2.820	(0.538)	1.273	(0.063)	-3.188	0.050
14:0	0.845	(0.045)	4.303	(0.503)	0.025	(0.061)	-5.314	0.013
14:1	0.095	(0.095)	0.417	(0.037)	0.133	(0.035)	-3.777	0.033
16:0	12.750	(0.090)	15.030	(0.650)	16.029	(0.258)	-2.711	0.073
16:1	5.415	(0.425)	6.527	(0.291)	7.305	(0.392)	-2.263	0.109
17:0	0.080	(0.080)	0.133	(0.024)	0.495	(0.090)	-0.793	0.485
17:1	1.110	(0.760)	0.317	(0.048)	0.159	(0.074)	-1.392	0.258
18:0	1.975	(0.405)	2.027	(0.173)	26.085	(2.457)	0.138	0.899
18:1	52.420	(0.230)	52.443	(2.047)	27.288	(2.387)	0.009	0.994
18:0+								
18:1	54.395	(0.175)	54.470	(1.876)	53.647	(0.614)	-0.031	0.977
18:2	26.705	(2.285)	7.173	(1.320)	17.311	(0.693)	-8.108	0.004
18:3	0.610	(0.610)	1.800	(0.496)	2.322	(0.634)	1.514	0.227
20:0	1.230	(0.750)	0.477	(0.068)	0.036	(0.027)	1.331	0.275
20:3	0.070	(0.070)	0.550	(0.275)	0.003	(0.003)	1.336	0.274
20:4	0.065	(0.065)	0.133	(0.004)	0.217	(0.021)	1.405	0.255
20:5	0.435	(0.435)	0.097	(0.049)	0.015	(0.015)	1.024	0.381
22:6	0.085	(0.085)	0.177	(0.090)	0.025	(0.025)	0.696	0.537

^a Two-tailed t-tests of significance of differences between high- and low-PUFA diets.

low-PUFA diet. The hydrogenated coconut oil used to formulate the low-PUFA diet contained moderate amounts of medium-chain FA's; animals fed this formulation had more 12- to 14-carbon FA's (P 's = 0.013 - 0.050) than those fed the high-PUFA diet.

The ground squirrels we studied, like marmots (*Marmota flaviventris*; Florant et al. 1990), have varying fatty acid composition of adipose stores in the wild and in the laboratory. These results do not agree with the contention that large amounts of 18:2 fatty acids are needed for hibernation (Frank 1991), because ground squirrels in the laboratory became torpid soon after we sampled their adipose tissues. In future work we will examine the relationship

between season, temperature, diet and tissue FA composition, and their effects on the ability of ground squirrels to become torpid.

Our study is the first documentation of FA composition of adipose tissues of a single species of hibernator from a variety of habitats, and the first demonstration that FA composition varies among sites for a given species. We predict that the FA composition of diets will vary with that of adipose tissue among sites.

Parasites

Helminth Community.--Necropsy revealed 4 new helminth host records (Table 29). *Heteromoxuris* sp. (pinworm) was found on Sites 3a and 5a via necropsy (Table 30) and

Table 29. Prevalence of helminth parasites from February to May, 1992 in Townsend's Ground Squirrels from the Snake River Birds of Prey Area based on necropsy examinations of animals collected monthly.

Month	Infected/ Examined	<i>Heteromoxuris</i> sp.	<i>Rictularia</i> sp.	<i>Mastophora</i> sp.	<i>Hymenolepis</i> sp.
FEB	5/23 (22%)	1 (4.3%)	0 (0%)	0 (0%)	4 (17.4%)
MAR	2/23 (9%)	0 (0%)	0 (0%)	0 (0%)	2 (8.6%)
APR	1/33 (3%)	0 (0%)	0 (0%)	0 (0%)	1 (3.0%)
MAY	16/37 (43%)	3 (8.1%)	6 (16%)	2 (5.4%)	5 (13.5%)
TOTAL	24/116 (21%)	4 (3.4%)	6 (5.1%)	2 (1.7%)	12 (10.3%)

Table 30. Number of Townsend's ground squirrels infected, and average number of worms harbored for each site, based on necropsy.

Site/ habitat	No. Individuals infected No. Individuals sampled	No. Individuals Infected/avg. No. worms ^a			
		Hy	He	R	M
1a/shrub	0/4	0	0	0	0
1b/shrub	0/3	0	0	0	0
2a/shrub	0/1	0	0	0	0
2b/shrub	0/2	0	0	0	0
3a/shrub	1/3	0	1/40	1/6	1/1
3b/shrub	0/9	0	0	0	0
4a/burn	1/5	1/2	0	0	0
4b/burn	2/8	0	0	2/8	0
5a/shrub	3/5	1/5	2/108	0	0
5b/shrub	0/5	0	0	0	0
6a/burn	2/3	1/1	0	1/22	0
6b/burn	0/6	0	0	0	0
7a/burn	1/6	1/7	0	0	0
7b/burn	1/6	0	0	0	1/1
8a/burn	2/5	2/4.5	0	0	0
8b/burn	2/6	1/41	0	1/7	0
9a/shrub	1/7	1/5	0	0	0
9b/shrub	0/4	0	0	0	0
10a/burn	1/5	1/1	0	0	0
10b/burn	3/6	2/11	0	1/9	0
CB/burn	2/12	1/8	1/6	0	0

^a Abbreviations are: Hy = *Hymenolepis* sp, He = *Heteromoxyuris* sp, R = *Rictularia* sp, M = *Mastophora* sp.

on Sites 2b, 4a, and 5a via fecal exam (Table 31). Site 5a was the only site with more than 1 ground squirrel infected with pinworm. *Hymenolepis* sp. (tapeworm) was found on 10 sites during necropsy (Table 31) and 3 sites via flotation (Table 31), for a total of 12 unique sites. Only Sites 4a, 4b, 5a, and 5b were included in the fecal sampling and of those, only 4a and 4b had more than 1 tapeworm infected ground squirrel. *Rictularia* sp. (intestinal worms) were not evident until May and were found only during necropsy in ground squirrels from 5 different sites (Table 30). *Mastophora* sp. (stomach worms) are quite rare, and only 1 worm was recovered from each of 2 ground squirrels from different sites (Table 30). Neither *Rictularia* sp. nor *Mastophora* sp. ova were recovered from any of the fecal samples. Gravid *Rictularia* sp. were collected, but the single female *Mastophora* sp. collected was not gravid.

Mastophora was found in the stomach, *Rictularia* and tapeworms were in the small intestine, and pinworms occurred in the cecum. The only case of multiple helminth infection involved a single animal from Site 3a infected with all 3 nematodes.

Parasites from 25 ground squirrels collected in Utah were reported by Jenkins and Grundmann (1973). They found 2 nematode species (*Physaloptera massino*, a stomach worm, and *Citellina triradiata*, a cecal worm), neither of which were found in this study. In addition, Piper, Hall, and Ransom found *Hymenolepis* sp. from Townsend's ground squirrels in 1907 from Pullman, WA. They deposited these tapeworms with the U.S. National Museum Parasite Collection, but apparently did not publish the data. We are now identifying our tapeworms to species.

Table 31. Estimates of helminth prevalence in the Townsend's ground squirrels from the Snake River Birds of Prey Area, 1992, using fecal flotation and necropsy information.

Site (Parasite) ^a	Necropsy No. Examined	Flotation and Necropsy					Range (Est. Prev.)
		Caps>3	Feb	Mar	Apr	May	
4a (Hy)	1/5	2/21	1/15	5/66	5/59	2/18	
%	20%	9.5%	6.6%	7.5%	8.4%	11.1%	9.5-21%
X CF (1.9)	—	—	12.5%	14.3%	16.2%	21.0%	(15.0%)
4b (Hy)	0/8	0/10	0/25	5/65	1/47	0/18	
%	0%	0%	0%	7.6%	2.1%	0%	0-14.4%
X CF (1.9)	—	—	0%	14.4%	4.0%	0%	(6.5%)
5a (He)	2/5	8/14	5/10	7/28	14/38	3/37	
%	40%	57%	50%	25%	37%	8.1%	8.1-115%
X CF (2.3)	—	—	115%	57.5%	85.1%	18.6%	(58.1%)

^a Hy = *Hymenolepis* sp. (tapeworm), He = *Heteromoyxuris* sp. (pinworm).

The difference in parasite community between the Utah squirrels examined by Jenkins and Grundmann (1973) and the SRBOPA ground squirrels is not unprecedented. Parasite communities frequently vary with geographical location (Pence et al. 1983) and even by habitat within a site (Rodenberg and Pence 1978; Boggs et al. 1990, 1991).

We observed differences between site types at the SRBOPA. Pinworm occurred more often on shrub sites (3 shrub vs. 2 burned), whereas both tapeworm and *Rictularia* were more likely to be found on burn sites. Tapeworm was present on 9 of 12 (75%) burned sites and 3 of 12 (25%) shrub sites. *Rictularia* were found 4 of 5 (80%) times on burn sites. Only 2 *Mastophora* were found; 1 on a burn and 1 on a shrub site. This suggests that burned conditions are more conducive to the intermediate hosts that

carry tapeworm and *Rictularia* or that increased densities of ground squirrels on burned sites contributes to improved transmission of these indirect lifecycle parasites.

Pinworms are direct lifecycle parasites, and ova probably can survive only about a week in the environment (Prince 1950; Gardener et al. 1976). Thus shade provided by shrubs probably increases ova survival somewhat, whereas ova desiccation is probably more rapid on the open burn sites.

Helminth Patterns.--Consistent increase of tapeworm prevalence over time on Site 4a may be related to arthropod consumption. Tapeworms require an intermediate host, and arthropod consumption by ground squirrels increased during the season (Table 32). Regression of beetle prevalence/month (Table 32) vs. estimated tapeworm

Table 32. Prevalence of stomach ulcers and Arthropoda parts in Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992, by month from necropsies.

Month	% w/Arthropods		% w/Ulcers	
FEB	0%	(0/23)	4.3%	(1/23)
MAR	4.3%	(1/23)	8.7%	(2/23)
APR	15.2%	(5/33)	30.3%	(10/33)
MAY	56.8%	(21/37)	0%	(0/37)
TOTAL	33.3%	(27/116)	11.2%	(14/116) ^a

^a One animal with an ulcerated stomach had no date data.

prevalence/mo on Site 4a (Table 30) produces an R^2 of 0.95 ($P < 0.05$). In addition, both *Mastophora* (Dyer and Olsen 1967) and *Rictularia* (Rankin 1945) require arthropod intermediate hosts, and they only appeared in May, the month of highest arthropod consumption. No stomachs of ground squirrels infected with the direct lifecycle pinworm (0 of 4) contained beetle parts, but 4 of 12 tapeworm, 4 of 6 *Rictularia*, and 1 of 2 *Mastophora* infected ground squirrels did contain beetle parts.

Fecal float results show that pinworm prevalence was high from February through April, but declined in May. The decline might result in part from expulsion of nematodes prior to dormancy. It could also be caused by a decrease in the nutritional plane of ground squirrels and a concomitant decrease in nematode ova production or by nematodes becoming dormant in response to changing ground squirrel physiology prior to dormancy.

We did not examine the relationship of host density to infection since pinworms occurred on only 1 site, but we did find that there were no differences in prevalence between sexes nor was reproductive status of females affected. There was no relationship between prevalence and weight of infected vs. non-infected (captured > 3 times but never infected) ground squirrels. Infected ($n = 8$) and non-infected ($n = 3$) adult females both had pregnancy rates of 100%. This agrees with Gardener et al. (1976) who found that *Heteromoxuris deserti* had no effect on weight or reproduction in Ord's kangaroo rat.

We found that estimated pinworm prevalence in adults ($n = 44$) was greater than in juveniles ($n = 29$) (82% vs. 32%),

and analysis of infected ground squirrels captured > 3 times ($n = 8$) indicates that once infected, pinworms persist throughout the season.

No *Mastophora* or *Rictularia* ovum were observed in fecal samples and worms were recovered only in May from necropsied ground squirrels so no seasonal patterns were noted.

Helminth Overwinter Persistence.--Both pinworm and tapeworm species may be maintained in an obligate hibernator like the Townsend's ground squirrel by overwintering; 1) in the ground squirrel, 2) in a non-hibernating alternate host, or 3) in the environment.

Tapeworm ova were recovered within 11 days of ground squirrel emergence. About 2 weeks is required for development before *Hymenolepis diminuta* or *H. citelli* (Ford 1967) begin shedding ova. Squirrels therefore may have consumed infected beetles soon after arousal and developed a patent infection. However, because no beetles were consumed by ground squirrels in February (Table 32), patent infections early in February probably result from redevelopment of dormant tapeworms already in the ground squirrel's digestive system. Ford (1972) demonstrated that *H. citelli* can overwinter in hibernating thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) and ova were shed within 2 weeks after arousal.

Pinworm ova were recovered within 10 days of emergence, and although the lifecycle of pinworm sp. is not completely elucidated, Gardener et al. (1976) believed that *Heteromoxuris* lifecycle paralleled that of *Syphacia oblevata*, the rat pinworm. Prince

(1950) demonstrated that *S. oblevata* requires 3 weeks to reach maturity and that ova did not remain viable in the environment for more than 1 week. Thus, pinworm infections in ground squirrels in mid-February probably resulted from parasites that overwintered in the ground squirrel. Chute (1960, 1964) suggested that nematodes overwinter in woodchucks (*Marmota monax*) and bats, and Cahill et al. (1967) found that 1 of 23 *S. tridecimlineatus* infected with *Nippostrongylus braziliensis* harbored a single adult worm following 10 weeks of hibernation. In addition, *Trichostrongylus tenuis* exhibits arrested development during the winter in red grouse (*Lagopus lagopus scoticus*; Shaw 1988), and abomasal nematodes in sheep undergo hypobiosis during winter in Iraq (Al-Kalidi and Al-Saeed 1991).

Stress and Parasitism.--During stomach examinations we found 8 of 29 (27.5%) juvenile and 6 of 87 (6.8%) adult ground squirrels had stress-related ulcers. Three of 13 ulcerated ground squirrels (23%) were recovered from shrub sites, while 10 of 13 (76%) were from burned sites. No site was recorded for 1 ulcerated animal. Burn sites had highest ground squirrel densities which may have stressed ground squirrels, contributing to formation of lesions. Because most animals were sacrificed within 6 hrs of capture, and none > 10 hrs after capture, ulcers were not capture artifacts. Additionally, necropsied ground squirrels were not part of the mark-recapture study, so lesions were not related to repeated trapping.

Juveniles with ulcers ($n = 7$) were significantly lighter than juveniles without ($n = 25$) ($68.6 \text{ g} \pm 15.7$ vs. 99.7 ± 29.5 , $P < 0.02$) but differences between ulcerated and non-ulcerated adults was not significant.

Lesions increased from February to April but were non-existent in May (Table 32). Numbers of animals/site increased through April but decreased in May. The decrease in density may have reduced stress enough to account for absence of ulcers in May. Alternatively, ulcerated ground squirrels may have died or dispersed.

Increased stress may cause increased parasite loads by various mechanisms including decreased immune function (Esch et al. 1975). Decreased immune function can also result from poor nutrition (Gerbase-Delima et al. 1975, Mann 1978). Nutritional intake at the SRBOPA this year was probably lower than normal due to dry conditions and lack of forage. If these stressors resulted in higher parasite loads at the SRBOPA in 1992, then at least 2 predictions should be valid: (1) ulcerated ground squirrels should have higher parasite prevalences than non-parasitized ground squirrels, and (2) parasite prevalence should increase with increasing stress. Neither appear to be true. Ulcerated ground squirrels had only slightly higher parasite prevalences than non-ulcerated ground squirrels (29% [4 of 14] vs. 23% [35 of 112]), and necropsy results revealed no helminth patterns. Based on fecal flotations, only tapeworm prevalence on Site 4a (the highest density site) showed a consistent trend. Prevalence increased from February to May (Table 31). Since ulceration rate was zero in May, stress probably cannot account for the tapeworm pattern on Site 4a. Rather, increased arthropod consumption as discussed above was probably more closely related to the tapeworm patterns seen on Site 4a.

Helminth Prevalence Estimates.--Helminth prevalence estimates were formulated based on necropsy and flotation results. Fecal

material from necropsied ground squirrels that harbored pinworms revealed that 2 of 4 (50%) were positive (Table 31). Percent recovery of pinworm ova also was determined in known positive ground squirrels (positive = all captures subsequent to a capture for which ova were recovered). Of the 53 floats from known positives, 23 (43%) contained ova. By combining the necropsy ova recovery rate and the fecal flotation ova recovery data, estimated recovery of ova from infected ground squirrels is 25 of 58 (43%). Thus 2.3 (100/43) more infections may have occurred than we detected. All raw results were therefore multiplied by 2.3. Estimated prevalence of pinworm on Site 5a (the only site with sufficient ova detection to use a number of comparative measures) was calculated by averaging the following measures: 1) Prevalence of pinworm on Site 5a resulting from necropsies; 2) Fecal float results from all ground squirrels on Site 5a captured > 3 times (animals captured > 3 times from which ova were never recovered are probably not infected); and 3) Prevalence of infection by month for all captures. Estimated prevalence for pinworm on Site 5a is 55% (Table 31). Because flotation for human pinworms (*Enterobius vermicularis*), a closely related species, detects only 1 in 4 active infections (Chandler and Read 1961) and detection of *Syphacia oblevata* is almost impossible using fecal material (Prince 1950) our estimates are probably conservative. Similar calculations were made for tapeworm on Site 4a (14%) and 4b (6.5%) (Table 31).

The correction factors developed can be applied to information gathered in subsequent years, and will allow year by year comparisons of infection prevalence. In addition, they provide useful indicators of

overall infection that can be used to assess effects of parasitism on populations. No correction factors were developed for *Rictularia* sp. or *Mastophora* sp. because ova from those nematodes were never found.

Blood.--Serum samples have not been analyzed, and only 4 of 122 blood smears appear abnormal, but definitive diagnosis has not been completed.

Eimerian Community.--Numerous studies have examined the coccidia of various spermophilines, but this is the first to examine ground squirrel. A total of 936 samples was examined from 487 individuals across the 8 parasite study sites. We found 7 species of *Eimeria* (Table 33), 4 of which were new host records, and 3 were new species. The 4 described species have been reported from a number of sciurids (Levine and Ivens 1990), and the 3 new species will be fully described and published in 1993.

Eimeria sp. 4 (E4), *Eimeria callospermophili* (E1), and *Eimeria bilamellata* (E3) occurred on 8 of 8 (100%), 7 of 8 (87.5%), and 7 of 8 (87.5%) sites respectively. However, E1, E4, and *Eimeria* sp. 2 (E2) occurred in the greatest number of individuals (Table 34). The number of fecal samples examined is positively correlated with number of species observed (Fig. 10), thus low-density sites may harbor fewer parasites simply due to a founder effect. Site 5b had the greatest prevalence of eimerians; this site also had an unusually low proportion of known-age yearlings reproductive (see section on litter production above). We don't know whether these anomalies are causally connected.

Eimerian Patterns.--Adult densities less than 0.90 animals/ha were positively correlated with eimerian prevalence ($R^2 =$

Table 33. *Eimeria* species observed in Townsend's ground squirrels from the Snake River Birds of Prey Area, 1992. All measurements are in microns.

Species ^a	n	Oocyst		Sporocyst		Wall	Rough(R) or Smooth (S)	Cap width
		length	width	length	width			
E1	60	21.3	18.9	9.3	6.7	1.0	S	—
E2	65	24.1	21.0	13.3	7.5	1.5	S	—
E3	41	32.3	27.3	16.5	10.0	1.6	R	7.1
E4	68	22.7	19.6	11.9	7.2	1.2	S	—
E5	32	36.0	29.0	15.4	10.3	1.6	R	—
E6	32	27.9	24.0	14.1	8.7	1.8	S	—
E7	50	15.0	12.8	8.3	5.3	1.0	S	—

^a E1 = *Eimeria callospermophilii*, E2 = *Eimeria* sp. 2 (Undescribed), E3 = *Eimeria bilamellata*, E4 = *Eimeria* sp. 4 (Undescribed), E5 = *Eimeria larimerensis*, E6 = *Eimeria* sp. 6 (Undescribed), E7 = *Eimeria beecheyi*.

Table 34. Prevalence of parasite infection in Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992, by site and species from fecal flotation data. Some individuals may be infected with more than 1 eimerian.

Site	#Ind	E1	E2	E3	E4	E5	E6	E7	Tot. Captures
1a	51	20% (10)	2% (1)	6% (3)	27% (14)	0% (0)	4% (2)	2% (1)	68
1b	23	17% (4)	0% (0)	0% (0)	39% (9)	4% (1)	4% (1)	0% (0)	48
2a	14	0% (0)	7% (1)	7% (1)	14% (2)	0% (0)	0% (0)	0% (0)	15
2b	17	12% (2)	0% (0)	6% (1)	18% (3)	0% (0)	6% (1)	0% (0)	17
4a	107	29% (31)	7% (8)	2% (2)	19% (20)	5% (5)	1% (1)	5% (5)	228
4b	109	39% (42)	15% (16)	11% (12)	38% (41)	1% (1)	5% (5)	4% (4)	204
5a	73	27% (20)	5% (4)	4% (3)	36% (26)	1% (1)	0% (0)	1% (1)	166
5b	85	51% (43)	19% (16)	5% (4)	34% (29)	4% (3)	7% (6)	12% (10)	183

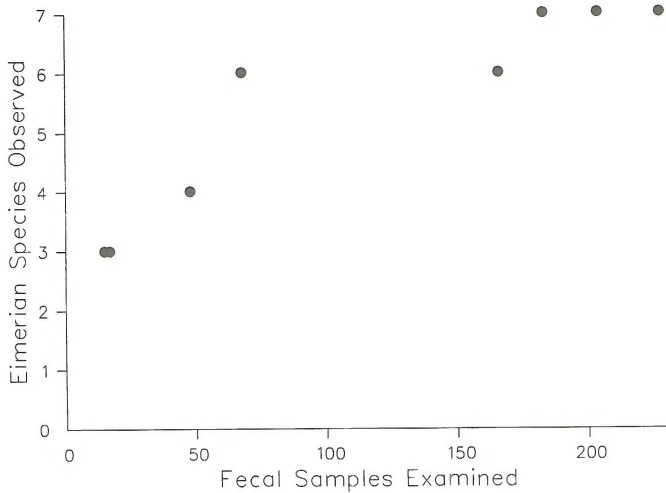


Fig. 10. The relationship between the number of fecal samples examined and the number of eimerian species observed.

0.95, $P < 0.02$) while adult densities > 0.90 animals/ha averaged $58\% \pm 8$ SD (Fig. 11). This suggests that environmental saturation with oocysts occurs at low ground squirrel densities.

Age and Sex

No difference in prevalence was observed between sexes, but age was significant (Fig. 12). Juveniles ($n = 185$ from all 8 sites) were less heavily infected than adults ($n = 320$ from all 8 sites) ($31\% \pm 7$ vs. $66\% \pm 9$, $P < 0.001$). Peak juvenile infections may have occurred during the 3-week period after birth when juveniles remain underground and were not sampled.

Preliminary examination of average weights and pregnancy rates of infected vs. never infected ground squirrels indicates that neither seems to be affected by eimerian infection, but more rigorous analysis has not yet been completed.

Date

Eimeria patterns by date were fairly constant between sites, so date trends were analyzed using the complete data set. Species E1, E2 and E4 showed clear date-related trends (Fig. 13). Prevalence of the other species was too low to discern patterns.

Eimeria prevalence for E1 and E2 decreased (Table 35) following host emergence, whereas E4 had a mid-season peak before declining (Fig. 13 and Table 35). Prevalence also decreased significantly over time for all captures (Table 35).

The mid-season increase of E4 (Fig. 13) may be due to temporal habitat partitioning by eimerians. Captive Townsend's ground

squirrels ($n = 7$) inoculated concurrently with E1, E2 and E4 consistently shed E1 first followed by E2 and then E4 (unpubl. pers. obs.). This suggests that temporal habitat partitioning does occur.

At least 2 hypotheses may explain the decline of *Eimeria* during the ground squirrel non-torpid season: (1) Decrease of oocyst viability due to drought conditions as the SRBOPA throughout the 1992 season, and/or (2) acquired immunity to *Eimeria* infections. Rainfall at the SRBOPA from February to June 1992 was low; in another study at the Sevilleta Long Term Ecological Research Site near Socorro, NM, eimerian prevalence in heteromyid and cricetid rodents decreased following an exceptionally dry year (Duszynski, unpubl. data). If this occurs at the SRBOPA, then infection patterns reflected by eimerian prevalences in ground squirrels in February 1993 should be low rather than high as seen in February 1992 (Fig. 12). Weather at the SRBOPA in 1991 was damp and cool (National Weather Service, Boise, ID).

Alternatively, decline may have been due to acquired immunity resulting in progressively fewer susceptible individuals. Immunity to E1, E3, and E5 has been demonstrated in *S. armatus* (Anderson 1971).

Mechanisms of immunity to coccidia are not completely understood, but continual exposure may be needed to sustain immunity (Rose 1982). During hibernation this stimulus may be lost, resulting in elimination of immune response over the 7-8 months that ground squirrels are dormant. If this occurs then all ground squirrels will be susceptible to infection in February 1993, and eimerian prevalences should be as high as in February 1992.

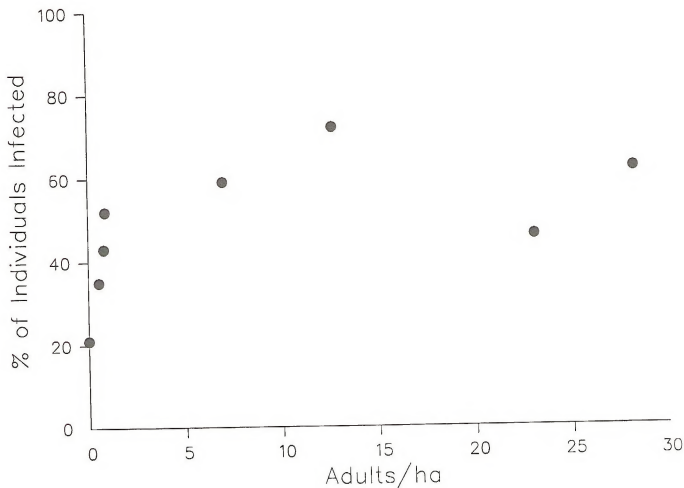


Fig. 11. Relationship between host density and *Eimeria* prevalence. Information from animals captured repeatedly was condensed into a single record so that prevalence is not a reflection of total captures, but rather of the unique individuals on the site. Repeated capture of individuals increased the likelihood of observing an infection, but this was not corrected for.

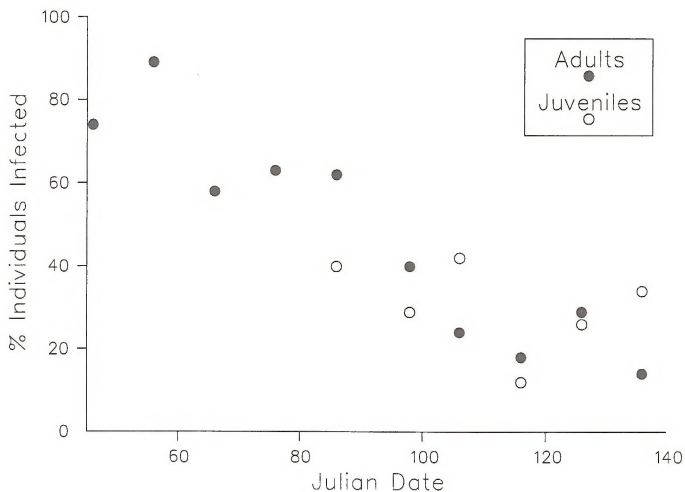


Fig. 12. Prevalence of all *Eimeria* by Julian date in juveniles (185 individuals; 217 capture events) and adults (320 individuals; 683 capture events). Data are lumped into 10-day intervals and all duplicate records are pooled, thus each data point is made up of unique individuals.

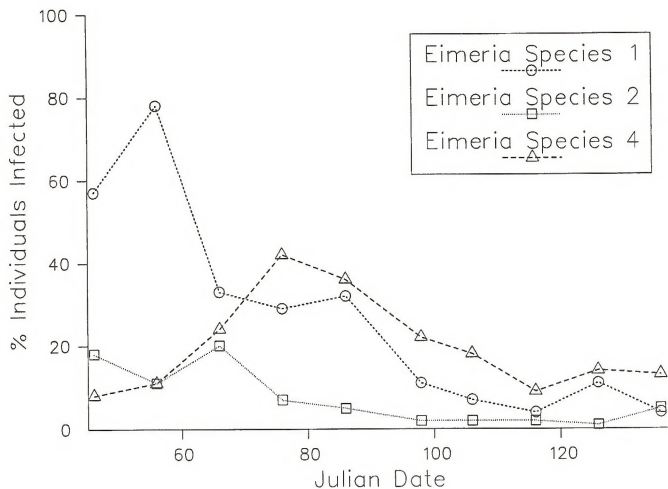


Fig. 13. Prevalence of the 3 most common *Eimeria* species by Julian date in 487 Townsend's ground squirrels captured 900 times. Data are lumped into 10-day intervals and all duplicate records are pooled, thus each data point is made up of unique individuals.

Table 35. Regression of prevalence against Julian date for the 3 most common *Eimeria* spp. found in Townsend's ground squirrels at the Snake River Birds of Prey Area, 1992, and for all eimerian infections combined.

Species	Date Range	R^2	P-value
E1	46-136	0.76	0.001
E2	46-136	0.61	0.005
E4	46-136	0.00	0.07
E4	76-136	0.81	0.004
All 7 E	46-136	0.86	<0.001

Our results differ from Shults et al (1990) who found no consistent patterns when examining > 1,000 Wyoming ground squirrels (*S. elegans*) from 4 sites for 4 years in Wyoming, and from Stanton et al. (1992) who stated that preliminary analysis of longitudinal data from Wyoming ground squirrels revealed no date-related trends. Wyoming ground squirrels share 4 eimerians with Townsend's ground squirrel (E1, E3, E5, E7). Perhaps since the latter authors necropsied ground squirrels subsequent changes in host-parasite interactions influenced their results. Forrester et al. (1977) necropsied 182 gray squirrels (*Sciurus carolinensis*) collected monthly over a 1-yr period in Florida. No trends in *Eimeria* prevalence were detected.

Analysis of infections in ground squirrels captured > 3 times ($n = 60$) showed that 72% (43) were infected with at least 1 eimerian during the season, and 28% (17) were never infected. Of the 43 infected,

53% (23) had more than 1 eimerian, and 65% (28) were infected on more than 1 date.

To develop a better understanding of parasite population dynamics on various habitat types over time, and to better assess the effects of parasites on the ground squirrel population, we plan to continue collecting fecal samples from females on the 8 parasite collection sites.

■ PLANS FOR NEXT SEASON

Because of the severity of the 1992 drought, we expect that densities will be very low and we will have to trap over large areas to achieve adequate sample sizes. We will continue the livetrapping on all sites. We will begin explicit spatial modeling of ground squirrel population dynamics over a broader area of the SRBOPA, using existing GIS information. We will continue the parasite surveys and laboratory work, as well

as monitoring of fat levels and survival. Diet work will continue but we will also include analyses of fat and nutrient content of diet items. We will do some experimental feeding of captive ground squirrels to calibrate fecal analysis with actual diet. Monitoring of marked holes will continue, and we will count holes on our sites to provide additional information on hole/density relationships. We will continue the behavioral observations and will test biophysical models that predict the combination of air temperature, wind speed, and solar radiation under which ground squirrels can be above ground.

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Habitat Classification and the Ability of Habitats to Support Populations of Townsend's Ground Squirrels and Black-tailed Jackrabbits

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Annual Summary

*I sampled vegetation and counted burrows of Townsend's ground squirrel (*Spermophilus townsendii*) at 166 sites randomly located throughout the Integration Study Area (ISA) and Orchard Training Area (OTA), within the Snake River Birds of Prey Area (SRBOPA). Burrow counts were higher in 1992 than in 1991 on 53 historical transects (1992: 196.3 ± 21.8 ; 1991: 131.1 ± 21.2) and on randomly located sites (1992: 262.0 ± 13.6 , $N = 166$; 1991: 169.0 ± 15.8 , $N = 115$). I also repeated burrow counts at biweekly intervals from 18 May - 28 July on 5 transects established in each of 5 habitats to calibrate results to a common base period. Number of burrows on calibration transects declined after the ground squirrel immergence period in mid-June and suggested that comparison of burrow counts across the sampling period was not valid. Attempts to adjust burrow counts by linear and curvilinear relationships determined in calibration transects produced spurious results. Therefore, statistical analysis of burrow counts with habitat variables was not attempted. Recommendations for burrow counts in 1993 include collapsing the sampling period to a 3-4 week period in early June to eliminate the need to adjust counts.*

*Densities of black-tailed jackrabbits (*Lepus californicus*) along spotlight transect routes were estimated at 0.15/ha (0.13-0.18, 95% C.I.) during winter 1990-91, and at 0.92 (0.71-1.20, 95% C.I.) in spring 1992. Jackrabbits were in a peak year of the population cycle. Jackrabbit densities were higher on transects in the OTA compared to transects outside the OTA for both winter and spring surveys. Jackrabbit densities were similar on transects south and north of the drift fence for both winter and spring surveys.*

▪ OBJECTIVES

1. To assess influence of military activities and livestock use on habitats and abundance of Townsend's ground squirrels and black-tailed jackrabbits.
2. To determine habitat correlates of Townsend's ground squirrel abundance and establish permanent transects that will be resampled at specified intervals for long-term monitoring of vegetation and Townsend's ground squirrels.
3. To monitor the relative abundance of Townsend's ground squirrels on 53 historical transects established in 1982 within the Snake River Birds of Prey Area.
4. To determine the temporal variation in burrow counts data for calibrating results to a common time frame.
5. To estimate jackrabbit densities from night spotlight counts along historical and newly established transects.

▪ INTRODUCTION

Abundant populations of Townsend's ground squirrels and black-tailed jackrabbits are needed to maintain one of the world's highest densities of nesting raptors in the Snake River Birds of Prey Area (SRBOPA) (U.S. Dep. Inter. 1979, Steenhof and Kochert 1988). In recent years, public concerns were raised that intensive grazing (Yensen 1980), extensive wildfires (Kochert and Pellant 1986), and long-term military activities in the Orchard Training Area (OTA) had

influenced habitat and prey communities in the SRBOPA. The purpose of Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project (BLM/IDARNG) is to evaluate the influence of these activities and provide an accurate description and spatial delineation of habitats and prey communities within the SRBOPA.

▪ METHODS

Townsend's Ground Squirrels and Habitats

Selection of Random Sampling Locations

--I sampled habitats and prey within the Integration Study Area (ISA) of the SRBOPA, including the OTA. I randomly selected 1,000 sites at the beginning of the study (Knick 1991); number of sites was apportioned between the ISA and the OTA relative to their respective areas (ha). In 1992, I sampled 166 points, including 14 points established <400 m from agriculture fields. These sites were sampled in response to apparent widespread squirrel movements to agricultural regions because of drought conditions elsewhere. All sites were marked in the field by a single metal fence post, and their position was recorded by a Global Positioning System for future studies of long-term changes (e.g., Anderson and Holte 1981, Turner 1990).

Townsend's Ground Squirrels.--Numbers of Townsend's ground squirrel burrows were counted in 5 x 400-m transects (Fig. 1) from 6 May through 6 August. An observer recorded all ground squirrel and badger (*Taxidea taxus*) burrows in the strip. Criteria to distinguish active burrows from inactive included absence of wind-blown

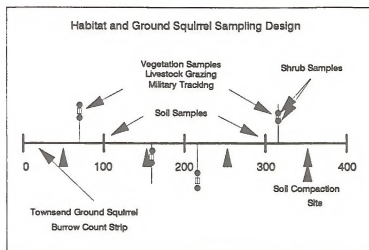


Fig. 1. Design for sampling habitat and Townsend's ground squirrel burrows at randomly located sites.

debris or spider webs, presence of claw marks or feces at the burrow, presence of trails emanating from the burrow, observation of squirrels, or absence of plant roots from burrow ceiling (Peterson and Yensen 1986, Yensen et al. 1992). I define "active" to represent actual status strictly at the time of sampling, rather than the looser criteria used in previous years that defined active to include the entire season (Knick 1991). I also assigned a high or low certainty factor to active/inactive status. Thus, each burrow was classified into 1 of 4 categories: active-certain, active-uncertain, inactive-uncertain, and inactive-certain.

Yearly sampling also was continued on 53 of 54 previously established 400 x 5-m strip transects to permit calibration and reference to previous research (Peterson and Yensen 1986, Yensen et al. 1992). I also sampled 10 transects previously established to monitor effects of burns in shadscale

(*Atriplex confertifolia*) habitats (Groves and Steenhof 1988). Transect #21 was no longer included in the sample of historical transects because of our inability to locate this transect since last sampling in 1989. Burrow densities were compared between random and historical transects by Student's *t* test (PROC TTEST, SAS Statistical Institute 1988).

Calibration Transects for Burrow Counts.--Decreasing squirrel activity and potential changes in our ability to accurately classify active status of burrows during the sampling period were calibrated by repeated sampling on established transects. The sample unit was the 5 x 400 m transect, and I established 5 transects each in sagebrush (*Artemisia tridentata*), winterfat (*Ceratoides lanata*), sagebrush-winterfat mosaic, a native perennial grassland of Sandberg's bluegrass (*Poa secunda*) and bottlebrush squirreltail (*Sitanion hystrix*), and a grassland dominated

by cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola iberica*) for calibration. Calibration transects were sampled biweekly from 18 May to 28 July. I determined either a linear or nonlinear relationship (PROC REG, PROC NLIN, SAS Statistical Institute 1988) for each category of active or inactive status in the transects over the sampling period. The equation describing that relationship was then used to adjust burrow counts at Study 5 sampling sites to a base date of 29 May (Julian date

150). The 4 adjusted activity categories were summed to obtain a total number of burrows for each transect.

Vegetation.--Vegetation, soils, and military and grazing information were sampled on ≥ 4 50-m transects perpendicular to the center line of the 400-m strip transect (Fig. 1, Table 1). At least 1 50-m transect was randomly located within each 100-m segment (Fig. 1). Therefore, each site effectively sampled a 100 x 400-m area (4 ha).

Table 1. Variables measured on strip transects for counting burrows of Townsend's ground squirrels. Food items will be determined from analysis of fecal pellets (Van Horne et al., this volume).

Variable	Data Type
No. TGS Burrows	Continuous
No. Badger Burrows	Continuous
Plant Species	Diversity index; Species richness
Food Items	Percent
Plant Species Cover	Percent
Canopy Cover	Percent
Bare Ground	Percent
Shrub Height	Continuous
Height to Canopy	Continuous
Soils	Continuous
% Clay	
% Sand	
% Silt	
% Nitrates	
% Organic Content	
Soil Depth	Continuous
No. cow fecal pats	Continuous, categorical, or binomial
No. sheep feces	Continuous, categorical, or binomial
No. Livestock Tracks	Percent Cover
Pocket gopher mound	Percent Cover
No. tank tracks	Percent Cover, categorical, or binomial

I sampled vegetation (species composition, frequency, canopy cover, % bare ground) by point intercept (Floyd and Anderson 1982) from 1 5-m section at randomly-determined points on each 50-m transect (Fig. 1). The sample unit consisted of 1 5-m section. The number of sample units with single 5-m sections needed to determine vegetation characteristics was assessed in the field by calculating a running mean of the 4 most abundant categories (Grieg-Smith 1983) and ranged from 7-11. Additional transects needed to obtain a stabilized mean were added at randomly selected points along the entire 400-m burrow count transect.

When shrubs were present, shrub density, mean shrub height, mean shrub height from ground to canopy, and presence/absence of canopy was determined from 20-m² (2.52-m radius) plots (Asherin 1973). Number of shrubs needed for sampling was calculated from a running mean. Shrub plots were established at each end of the 5-m sections for vegetation sampling by point frame (Fig. 1).

Species richness (S , number of species present) and species diversity were determined for total species composition at a sampling site. The diversity index was $H = 1/\sum p_i^2$ where p_i was the proportion of the i th species in the total sample (N_i/N) (Hill 1973, May 1981a). This index equaled 1 when a single species dominated the sample; higher values resulted from increasing number of species and evenness of distribution.

Habitat class was assigned to each transect based on the classification scheme developed

from previous vegetation surveys (Table 2) (Knick et al., this volume). I also grouped into shrub (all Class 1A, 1B, and 1C), grass (all Class 2A and 2B), and disturbed (all Class 1D) sites in the analyses.

Soils.—Soil samples were collected at the 100 and 300-m points along the burrow count transect (Fig. 1). At each point, I collected samples from the surface and at a 1-m depth to determine soil texture. Soil samples were sent to the University of Idaho for analysis of soil texture, percent organic content, and percent nitrates. I used a canonical correspondence analysis (CANOCO, ter Braak 1988) to examine relationships between vegetation species and soil variables. Canonical correspondence analysis is a multivariate direct gradient approach for analysis of community variation relative to the environment (ter Braak 1986). In canonical correspondence analysis, the ordination axes of the set of species data (representing variation in the vegetation community structure) are constrained to be linear combinations of the environmental variables (soil variables), and species are assumed to have a unimodal response to the environmental gradients (ter Braak and Prentice 1988). The ability of soils to predict habitat type was tested by a quadratic discriminant function with habitat type as the classification variable and soil variables as predictor variables (PROC DISCRIM, SAS Statistical Institute 1988).

Military Use and Vegetation.—Tracking intensity was determined by categorical estimation (presence = 1; absence = 0) of military tracks along each 100-m line

Table 2. Habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area from 1987-92. Habitat classes are described in Knick et al. (this volume).

1. Shrublands

A. High Density Shrub (Cover > 25%)

1. Sagebrush
2. Shadscale
3. Winterfat
4. Greasewood
5. Budsage
6. Nuttall's saltbush
7. green rabbitbrush
8. gray rabbitbrush

B. Medium Density Shrub (Cover >5 and <25%)

1. Sagebrush
2. Shadscale
3. Winterfat
4. Greasewood
5. Budsage
6. Nuttall's saltbush
7. green rabbitbrush
8. gray rabbitbrush

1. D. High disturbance regions

1. Russian thistle >15%, cheatgrass >25%, native grass >25%
2. Russian thistle >15%, cheatgrass >25%, native grass <25%
3. Russian thistle 15-35%, cheatgrass <25%, native grass <25%
4. Russian thistle > 35%, cheatgrass <25%, native grass <25%
5. Russian thistle >35%, cheatgrass <25%, native grass >25%
6. Russian thistle 15-35%, cheatgrass <25%, native grass <25%

2. Grasslands

A. Low disturbance

1. native perennial grasses > 25%, cheatgrass <25%
2. native perennial grasses < 25%, cheatgrass < 25%

B. High disturbance

1. Cheatgrass > 25%, native grasses <25%
 2. Cheatgrass < 25%, native grasses <25% segment of the 5-m wide transect
-

(Fig. 1). Percent cover of tracks was also determined from point frame counts. Relationship of military tracking to vegetation species was determined by Student's *t* tests (PROC TTEST, SAS Statistical Institute 1988). Sites were grouped based on presence or absence of military tracking.

Livestock Use and Vegetation.--At each burrow count transect, a categorical estimate (presence = 1; absence = 0) of cattle and sheep use was obtained along each 100-m segment (Fig. 1) from presence of fecal material, or tracks. Percent cover of livestock litter was determined from point frame counts. Vegetation and presence/absence of livestock were compared north and south of the drift fence using Student's *t*-tests (PROC TTEST, SAS Statistical Institute 1988). The drift fence is a boundary between winter (south of the fence) and spring-fall (north of the fence) grazing periods.

Statistical Analysis of Ground Squirrels and habitats.--Results from calibration transects suggest that any statistical analysis involving burrow counts must be erroneous. An extensive series of statistical tests, including direct and indirect gradient analyses, were outlined in the 1991 Annual Report for Study 5 (Knick 1991). When the burrow count methods are validated, these statistical analyses and results will again be presented.

Temporal and Spatial Analysis of Historical Burrow Counts.--I analyzed temporal relationships for sites sampled in consecutive years to determine possible density dependence in squirrel populations (May 1981b). Burrow counts (representing population size) at time $t+1$ was plotted

against burrows counted at time $t = 0$. In addition, the difference in counts between the yearly interval (representing population growth) was plotted as a function of counts. If density dependent mechanisms were present, both population size and growth rate should be related to initial population size. Larger populations under density dependent regimes should have smaller growth rates and maintain population size relative to smaller populations.

I examined spatial dependence in 1991 burrow counts at random locations to test the hypothesis that populations were related at some distance d ; with increasing distance, counts of population size were likely to be unrelated. I plotted the difference between burrow counts and distance with all possible combinations, $m(m-2)/2$, of m sites and compared population size within for <0.5, 0.5-1.0, 1.0-2.0, and >2.0 km categories by a 1-way Analysis of Variance (Sokal and Rohlf 1981). The purpose of this analysis was to define potential minimum distances for contouring burrow counts.

Numbers of burrows from 1992 sample locations were contoured in the ARC/INFO Geographical Information Systems software for comparison with raptor home ranges and foraging sites.

Jackrabbits

Jackrabbits were counted by spotlight at night between 2200 and 0500 hr (Smith and Nydegger 1985) by driving along previously established transects (Doremus et al. 1989). Winter surveys were conducted between 10 December 1991 and 10 January 1992. Spring surveys were conducted between 18 May and 27 June 1992. Each transect was driven 2 times on separate nights.

Because of potential differences in density estimates between new transects added in 1991 (Knick 1991) and historical transects, I compared the distribution of sighting distances and the density estimates between new and historical transects before pooling data to analyze population trend. Mean location of sample distances obtained on new and historical transects was compared by Wilcoxon 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) and their distribution by Kolmogorov-Smirnov 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) to determine if detection differences were present. Density estimates from new and historical transects were then compared by z test. A similar procedure was followed for all other pairwise comparison of transect results.

Densities of jackrabbits for 1992 and all previous years (1977-1991) were estimated using program DISTANCE (Laake et al. 1991), an upgraded version of the program TRANSECT (Burnham et al. 1980). I determined the model estimator (half-normal, uniform, negative exponential, hazard) that best fit the data from the lowest Akaike Information Criterion (Burnham and Anderson 1992, Lebreton et al. 1991) for analysis of distance data.

I compared estimates of jackrabbit densities between OTA and non-OTA transects north of the Snake River to determine regional differences based on presence of military training. I also compared jackrabbit densities north and south of the drift fence to determine regional differences relative to season of livestock grazing. Regional comparisons were done separately for winter and spring surveys.

Habitat types were not determined along transects but will be examined when an accurate GIS layer of vegetation for the SRBOPA is produced (Knick et al., this volume). I recorded habitat at each sighting (Table 2) and a categorical estimate of distance to nearest shrub cover for future comparison with habitat availability.

Sightings of kangaroo rats (*Dipodomys ordii* and *D. microps*), Nuttall's cottontail rabbits (*Sylvilagus nuttallii*), pygmy rabbits (*Brachylagus idahoensis*), and mice and voles (including *Lemmys curtatus*, *Microtus* sp., *Onychomys leucogaster*, *Perognathus parvus*, and *Reithrodontomys megalotis*) also were recorded on black-tailed jackrabbit spotlight transects. Number of sightings was not converted into a density estimate for these species.

■ RESULTS

I sampled 87 randomly located sites within the ISA and 64 in the OTA for Townsend's ground squirrels and habitat. In addition, burrow counts were conducted on 53 historical transects in the SRBOPA, 10 transects from shadscale burn regions (Groves and Steenhof 1988), and 77 transects established by Study 5 in 1991 (Knick 1991).

Townsend's Ground Squirrels and Habitats

Calibration Transects for Burrow Counts.--Total number of burrows declined through the sampling period for each calibration site and for the mean for all ISA sampling sites (Fig. 2). As expected,

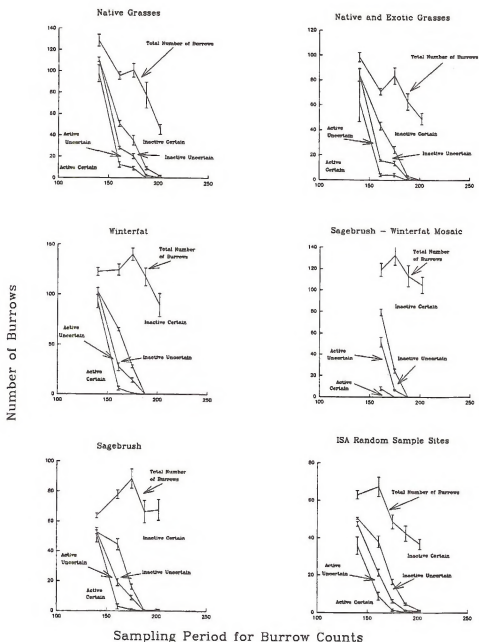


Fig. 2. Changes in mean numbers (\pm standard errors) of burrows counted on transects at 5 habitats for calibration of estimates to a common base period. Counts from ISA random sites were means of all sites sampled within the 2-week interval. Spaces between lines represent the number in individual categories.

number of active burrows decreased and inactive burrows increased during the season. The total number of burrows strongly declined after mid-June and the emergence period for ground squirrels.

Linear relationships were determined for active-certain and inactive-uncertain with either log- or square root transformations (Table 3). Quadratic equations were fit to the curvilinear trends in active-uncertain and inactive-certain categories (Table 3).

Although the data could be modeled by the equations with some precision, selection of the appropriate model as well as selection of the base period for calibration resulted in large estimates in the adjusted burrow counts (Table 4). Modeling individual categories was not reliable and contributed to adjustments that were not intuitively realistic. Because the number of inactive-certain burrows increased through the census period, adjustments to a earlier base period meant reducing the number in this category (Fig. 3). In contrast, because no active-certain burrows were counted at the end of the sample period, the adjustment to an earlier time was obtained by adding the intercept or predicted value for the chosen base period (Table 3).

Burrow Count Results.--I present the burrow counts for historical and random transects to identify trends only. Because of the calibration results, presenting statistical analyses and results is not valid. Burrow counts are total counts and were not adjusted.

Total number of burrows counted on 53 historical transects averaged 196.32 ± 21.75

($\bar{x} \pm \text{S.E.}$) and were higher than total number of burrows counted in 1991 (133.1 ± 21.2 burrows/ha) (Table 5).

Total number of burrows counted on 166 randomly located transects averaged 262.02 ± 13.58 and also were higher than 169.0 ± 15.8 total burrows/ha counted in 1991 for randomly established transects. Burrow counts at 14 sites near agriculture fields averaged 257.14 ± 30.60 compared to 223.00 ± 54.90 at 13 random sites conducted elsewhere in the ISA during the same period. Burrow counts in 1992 averaged 170.8 ± 17.0 compared to 1991 counts of 152.8 ± 19.3 for 77 random sites sampled in both years ($t = 0.70$, 152 df, $P = 0.49$).

Temporal and Spatial Analysis of Historical Burrow Counts.--Plots of burrow counts (representing population growth and population size) at time $t + 1$ relative to burrows counted at time t suggested that some density dependence was present in ground squirrel populations. Larger initial populations tended to have lower growth rates (Fig. 4) and to either decrease or maintain population size in the following year (Fig. 5). The cluster of points along the diagonal representing no change between years also suggests that yearly variations within populations are not totally chaotic but responsive to some density dependent mechanisms.

Numbers of burrows counted were statistically related to distance for the 4 categories in the 1991 burrow count data (Fig. 6) ($F = 22.25$, 3, 14,724 df, $P = 0.0001$) although the variation explained, R^2 , was $< 1.0\%$. Mean difference in burrow counts between site pairs was 102.1 ± 120.5

Table 3. Equations used for adjustment of ground squirrel burrow counts back to a base period. Number of burrows at each site was the sum of active-certain (Actc), active-uncertain (Actu), inactive-uncertain (Inu), and inactive-certain (Inc). Jday was the Julian Date.

Habitat	Adjustment Equation	F	P	R ²
Exotic Grass	Actc = $(\exp(4.87 - 1.13 * \ln(\text{Jday} + 1))) - 1$	126.66	0.0001	0.84
	Actu = $21.7 - (0.48 * \text{Jday}) + (0.002 * \sqrt{\text{jday}})$			
	Inu = $(\exp(5.01 - (0.08 * \text{Jday}))) - 1$ Inc = $8.42 + (1.92 * \text{Jday}) - (0.02 * \sqrt{\text{Jday}})$	224.16	0.0001	0.92
Native Grass	Actc = $(\sqrt{11.72 - 2.60 * \ln(\text{Jday} + 1)}) - 1$	507.82	0.0001	0.96
	Actu = $13.79 + (0.12 * \text{Jday}) - (0.006 * \sqrt{\text{jday}})$			
	Inu = $(\sqrt{6.45 - (0.079 * \text{Jday}))) - 1$ Inc = $12.72 + (2.63 * \text{Jday}) - (0.033 * \sqrt{\text{Jday}})$	43.37	0.0001	0.69
Sagebrush	Actc = $(\sqrt{8.23 - 1.88 * \ln(\text{Jday} + 1))} - 1$	314.52	0.0001	0.93
	Actu = $3.75 + (0.52 * \text{Jday}) - (0.010 * \sqrt{\text{jday}})$			
	Inu = $(\sqrt{16.51 - 3.80 * \ln(\text{Jday} + 1))} - 1$ Inc = $5.65 + (2.34 * \text{Jday}) - (0.02 * \sqrt{\text{Jday}})$	108.58	0.0001	0.85
Winterfat	Actc = $(\sqrt{11.23 - 2.64 * \ln(\text{Jday} + 1)}) - 1$	566.26	0.0001	0.96
	Actu = $12.37 + (0.38 * \text{Jday}) - (0.01 * \sqrt{\text{jday}})$			
	Inu = $(\sqrt{21.99 - 5.18 * \ln(\text{Jday} + 1))} - 1$ Inc = $9.08 + (4.36 * \text{Jday}) - (0.048 * \sqrt{\text{Jday}})$	244.92	0.0001	0.93
Winterfat - Sagebrush Mosaic	Actc = $(\exp(7.56 - 1.91 * \ln(\text{Jday} + 1))) - 1$	44.09	0.0001	0.72
	Actu = $118.12 - (4.66 * \text{Jday}) + (0.04 * \sqrt{\text{jday}})$			
	Inu = $(\sqrt{19.20 - 4.45 * \ln(\text{Jday} + 1))} - 1$ Inc = $-102.12 + (9.05 * \text{Jday}) - (0.09 * \sqrt{\text{Jday}})$	85.92	0.0001	0.83

Table 4. Changes in adjusted burrow counts relative to selection of base period. Equations used in calibration were presented in Table 3. The unadjusted counts were the mean for 166 transects sampled at random locations in the ISA.

Activity Category	Unadjusted Count	Counts Adjusted to: Base Period (Julian Date)			
		140	150	160	170
Active:					
Certain	11.7	198.5	19.8	7.9	3.8
Uncertain	6.0	15.3	16.2	14.2	12.5
Inactive:					
Certain	29.4	6.18	12.2	22.8	34.5
Uncertain	5.7	142.92	47.2	24.4	14.3
Total	52.9	309.97	87.4	68.9	63.8

(SD) for 14 pairs < 0.5 km apart, 82.7 ± 102.07 for 35 site pairs 0.5-1.0 km apart, 141.3 ± 141.6 for 806 site pairs 1.0-2.0 km apart, and 182.0 ± 158.6 for 13,870 site pairs > 2.0 km apart. Distances ranged from 0.162 - 70.11 km for all possible combinations of sites.

A high density region of burrow numbers was projected in the OTA was projected by a kriging total burrows counted at sample sites in 1992 (Fig. 7). The figure also demonstrated the extent of area sampled within the ISA by random sites and potential for overlapping with raptor foraging as part of the Integration Study.

Vegetation and Soils Analysis

Plant species richness ranged from 2 to 10 on 166 randomly selected sites. Diversity ranged from 1.00 to 5.46. Both species richness and diversity were similar between shrub, grass, and disturbed habitats as well as within individual habitat classes (F test, $P > 0.10$).

Military Use.--Plant species richness and diversity did not differ significantly in comparisons between ISA and OTA sites (t , 150 df, $P > 0.10$) and sites with/without tracks present (t , 150 df, $P > 0.10$). Cheatgrass was the only plant species with a

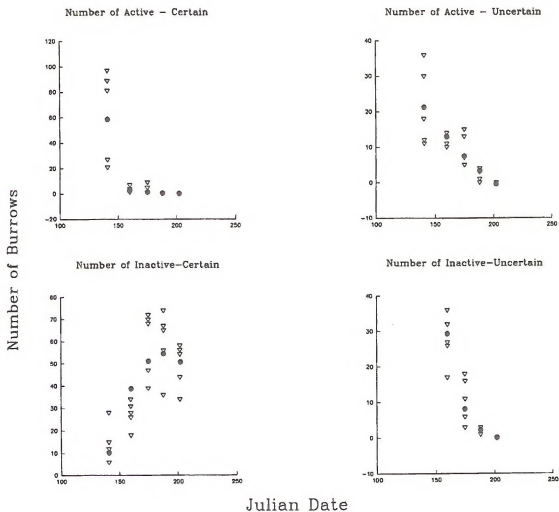


Fig. 3. Relationship between lines fitted by equations used for adjusting counts (solid symbols) and actual burrow count estimates (open symbols) by activity category in exotic grass habitats. Equations used for calibration lines are given in Table 3.

Table 5. Density of Townsend's ground squirrel burrows (n/ha) on 54 established transects in the Snake River Birds of Prey Area. Counts were obtained from 5 X 400 m transects using strip transect methodology. Data from 1982-1989 are from Yensen et al. 1992). Habitat descriptions for each site are given in Wheeler et al. 1989).

Transect	1982	1986	1987	1988	1989	1990	1991	1992
4	735	315	505	455	410	135	545	240
5	131	230	320	55	85	160	445	245
6	232	180	240	80	65	75	365	285
7	373	260	645	225	175	65	535	95
13	624	370	120	275	210	15	295	555
14	342	100	250	315	185	20	235	240
15	453	150	625	295	265	15	315	360
16	322	340	470	255	235	0	360	270
17	201	130	95	50	85	5	140	500
18	322	340	230	120	100	15	90	150
20	60	55	55	80	50	0	90	170
21	60	25	105	95	115	---a	---a	---a
22	483	35	70	50	35	20	90	290
23	70	40	95	85	85	30	15	270
24	131	35	55	65	40	25	15	160
26	584	5	170	80	165	140	310	475
33	101	70	155	60	70	135	390	430
34	242	30	55	35	25	45	15	295
35	322	120	195	25	135	225	400	135
50	393	105	115	60	70	70	250	385
51	111	45	30	50	45	45	160	355
53	121	15	15	20	15	0	10	445
54	201	15	30	0	0	10	100	425
55	262	20	145	5	150	15	145	335
56	363	270	560	170	200	35	175	335
57	201	180	330	170	230	25	310	355

^a Transect 21 was not located after 1989.

Table 5. Continued.

Transect	1982	1986	1987	1988	1989	1990	1991	1992
121	121	170	110	80	115	25	40	90
122	0	0	0	0	25	0	5	35
123	20	0	0	0	0	0	5	115
124	20	25	15	0	5	0	15	50
125	0	0	10	0	30	0	20	75
126	0	0	5	0	0	0	0	20
127	252	0	15	0	0	5	15	45
128	50	0	15	30	0	0	0	100
147	101	5	30	15	5	0	15	25
148	50	5	10	5	5	0	0	30
149	111	0	5	0	10	20	25	90
150	10	5	0	0	5	0	0	20
151	0	0	0	0	0	0	0	30
152	30	0	10	0	0	0	10	20
161	10	0	20	15	15	0	0	20
162	232	30	30	20	35	0	20	20
165	30	60	60	60	60	0	50	100
172	141	90	115	65	100	20	85	90
182	50	30	5	10	20	0	5	60
183	40	0	65	5	0	0	15	35
200	222	25	100	20	60	85	230	75
201	332	20	830	0	5	30	250	500
202	796	75	725	15	100	20	215	410
203	70	65	100	65	70	14	25	155
204	50	20	30	30	35	5	90	55
205	141	10	35	20	0	10	45	115
206	81	15	55	25	25	0	55	100
207	60	0	30	0	10	5	20	125
Total	10,460	4,130	8,105	3,655	3,955	1,575	7,055	10,405
\bar{x}	193.3	76.5	150.1	67.7	73.2	30.0	133.1	196.3

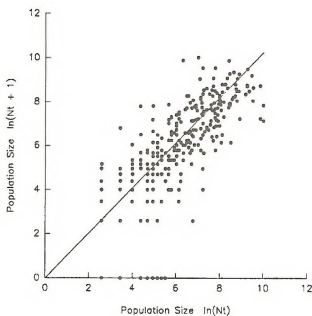


Fig. 4. Population size at time $t + 1$ relative to population size at time t . Points represent burrow counts from sites sampled in 2 consecutive years ($N = 288$).

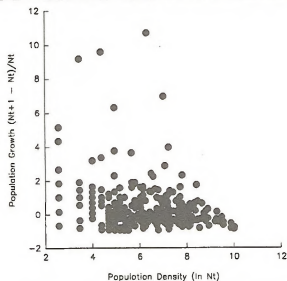


Fig. 5. Growth rate of populations, determined from difference in burrow counts, from time t to $t + 1$ for sites sampled in 2 consecutive years ($N = 288$).

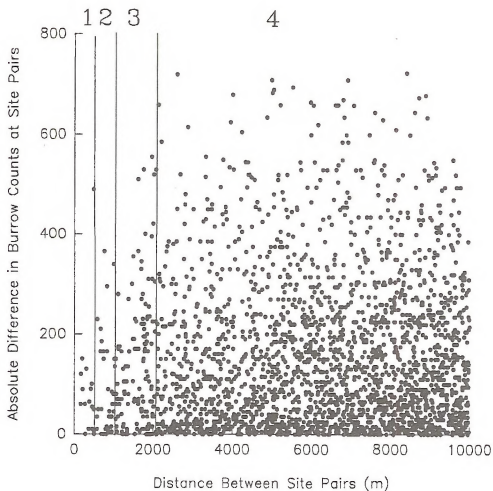


Fig. 6. Difference in burrow count estimates relative to distance between site pairs for all combinations of 115 sites sampled in the ISA in 1991. Categories 1-4 represent site pairs < 0.5, 0.5-1.0, 1.0-2.0, and > 2.0 km.

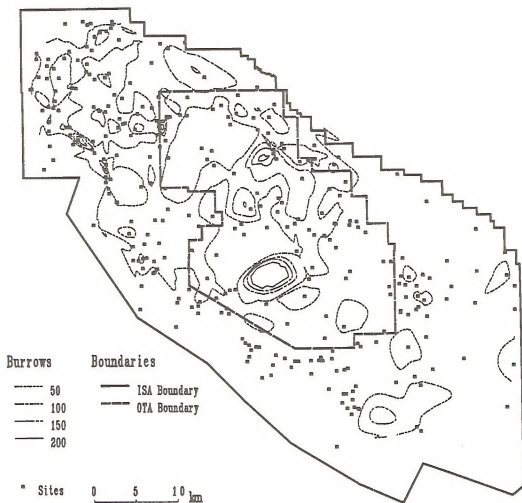


Fig. 7. Contoured map of numbers of burrows counted at random and historical sites in ISA during 1992.

significantly greater percent cover on tracked sites (7.22 ± 0.99 , $N = 100$) vs. untracked sites (1.18 ± 0.41 , $N = 66$) ($t = 3.08$, 164 df, $P = 0.025$).

Livestock Use.--Plant species richness and diversity did not differ significantly on sites that had presence of livestock vs. sites without (t , 150 df, $P > 0.10$).

Soils.--Soil (percent nitrates, percent organic content, and texture: percent clay, percent silt, percent sand) and percent cover of plant species were collected at 80 sites in 1991. The first 3 axes in the ordination of vegetation (species) data explained only 13.9% of the total variation (Table 6).

However, 83.8% of the variation in the vegetation - soils relation was explained in the first 3 axes of the regression between species and environmental (soils) variables

(Table 6). Winterfat, bud sage (*Artemisia spinescens*), and shadscale were strongly associated with sandy soils, and sagebrush was associated with % nitrates in the soil (Fig. 8). Using a quadratic discriminant function with habitat as the classification variable and soil variables as predictors, the posterior probability rate of misclassification was only 1.35% for 44 samples and 9 habitat types. The only reclassified observation was 2A2 (low density grassland) to 1D3 (disturbed habitat).

Table 6. Canonical correspondence analysis of plant species with environmental (soil) variables at 80 sites sampled in 1991.

	Canonical Correspondence Analysis Axes			
	1	2	3	4
Eigenvalues	0.226	0.169	0.112	0.042
Species-environment correlations	0.614	0.519	0.451	0.333
Cumulative percentage variance:				
of species data	6.2	10.8	13.9	15.0
of species-environment relation	37.3	65.2	83.8	90.8
Sum of all unconstrained eigenvalues	3.652			
Sum of all canonical eigenvalues	0.605			

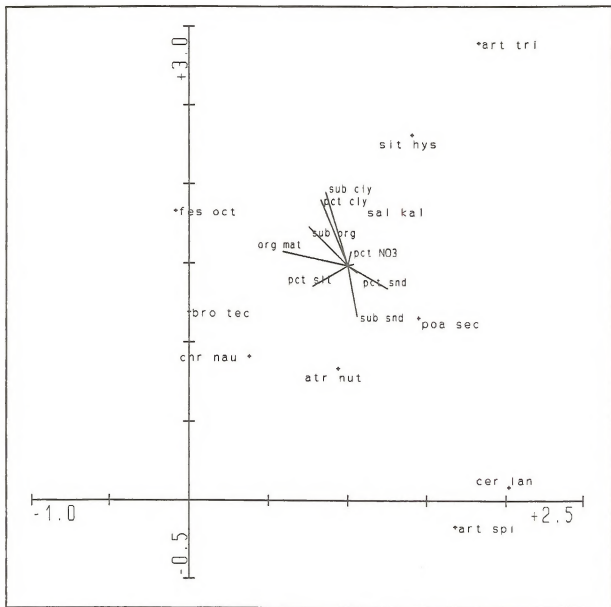


Fig. 8. Joint plot of vegetation species and soil variables from canonical correspondence analysis. Vegetation species were Bud sage (art spi), winterfat (cer lan), shadscale (atr con), cheatgrass (bro tec), green rabbitbrush (chr vis), six-weeks fescue (fes oct), sagebrush (art tri), and bottlebrush squirreltail (sit hys). Soil variables were % surface silt (pct silt), sand (pct sand), and clay (pct cly); % subsurface silt (sub silt), sand (sub sand), and clay (sub cly); % surface nitrates (pct NO3) and % subsurface nitrates (sub NO3); and % surface organic matter (pct org) and % subsurface organic matter (sub org).

Black-tailed Jackrabbits

Winter densities of black-tailed jackrabbits along all spotlight transect routes (603.62 km) were 0.15/ha (0.13-0.18, 95% C.I.). Density estimates for 14 traditional transects (0.15/ha, 0.13-0.18) (467.06 km) did not differ ($z = 0.40$, $P = 0.70$) from 7 transects added in spring 1991 (0.14/ha, 0.10-0.19) (136.56 km).

Jackrabbit densities were at in the high phase of their population cycle in spring

1992 (Fig. 9). Jackrabbit sightings in spring surveys on new and historical transects were similar in mean location ($z = 1.72$, $P = 0.09$) and distribution of distances ($D = 0.079$, $P = 0.12$). Spring densities were 0.92/ha (0.71-1.20) on historical transects (467.06 km) and 0.90/ha (0.58-1.38) on new transects (136.52 km) ($z = 0.08$, $P > 0.9$). I combined results from new and historical rabbit transects for depicting long-term trend (Fig. 9).

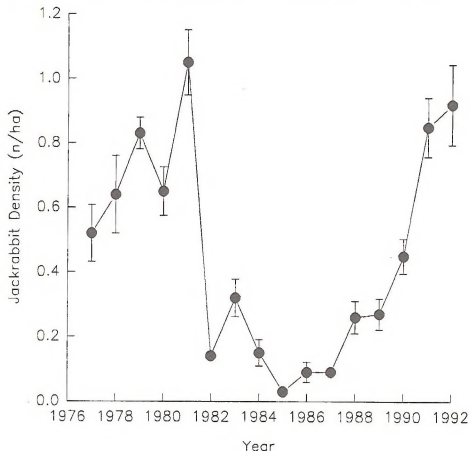


Fig. 9. Spring estimates of jackrabbit densities (\pm coefficient of variation) for the Snake River Birds of Prey Area from 1977 through 1992.

Jackrabbit densities were higher on transects inside the OTA than outside the OTA and north of the Snake River during both winter and spring surveys (Table 7), but the difference was significant only for the winter surveys. Jackrabbit densities were similar on transects north and south of the grazing drift fence for both winter and spring surveys (Table 8).

I also observed 10 Nuttall's cottontail rabbits, 8 pygmy rabbits, 1,170 kangaroo rats, and 47 mice and voles on spring spotlight transects. On winter transects, I counted 5 Nuttall's cottontail rabbits, 3 pygmy rabbits, 125 kangaroo rats, and 14 mice and voles.

DISCUSSION

Townsend's Ground Squirrels and Habitats Interpretation of population trends from historical transects, as well as correlations between populations and habitat qualities on new sample sites, remains linked to 2 factors. First, the relationship between any category or total numbers of burrows and actual numbers of ground squirrels in the population is still under investigation by Study 4 of the BLM/IDARNG Research Project (Van Horne et al. 1991). Second, the calibration transects revealed temporal variation in burrow counts that invalidated statistical analysis of within- or between year comparisons.

Table 7. Numbers of jackrabbits and density estimates for transects within the Orchard Training Area (military training) and Integration Study Area (no military). Densities were higher inside the Orchard Training Area during winter ($z = 3.71$, $P < 0.01$) but the results were not significant for spring ($z = 1.22$, $P = 0.24$) surveys. All transects were north of the Snake River.

Area	N	No./Ha	CV	95% C.I.
<u>Winter 1991-92</u>				
Military Training	144	0.35	17.4	0.25 - 0.49
No Military Training	224	0.12	9.9	0.10 - 0.14
<u>Spring 1992</u>				
Military Training	230	1.03	21.0	0.69 - 1.56
No Military Training	498	0.73	15.9	0.54 - 1.00

Table 8. Numbers of jackrabbits and estimates of densities for transects north (spring and fall grazing) and south (winter grazing) of the drift fence. Density estimates did not differ significantly between transects during winter ($z = 0.78$, $P = 0.46$) and spring ($z = 0.68$, $P = 0.52$) surveys. All transects were north of the Snake River.

Area	N	No./Ha	CV	95% C.I.
<u>Winter 1991-92</u>				
North of Drift Fence	86	0.13	15.5	0.10 - 0.17
South of Drift Fence	257	0.15	10.6	0.12 - 0.18
<u>Spring 1992</u>				
North of Drift Fence	165	1.05	23.6	0.67 - 1.66
South of Drift Fence	563	0.86	15.5	0.63 - 1.16

The calibration transects demonstrated the dynamic temporal variation in burrow counts. Numbers of burrows counted in grassland sites decreased, and then increased by sampling period 3 (Julian Date 175). Strong winds in early June (Julian Dates 153-160) may have covered burrows, followed by continued burrowing by juvenile ground squirrels that were still active prior to emergence in mid-June. The smaller range in variation for calibration transects in the sagebrush or sagebrush-winterfat mosaic may be due to reduced wind disturbance at microhabitats relative to the more open sites.

Comparison of burrow counts at agricultural sites with samples elsewhere in the ISA also illustrates the tenuous basis for using burrow

counts as estimators of population size. Observations by field personnel suggested that ground squirrels were locally abundant at agricultural regions because of food availability. Although burrow counts were higher at 14 agricultural sites compared to 13 sites in the ISA, the conclusion was not statistically warranted. Although observer perceptions could be misleading (that is why I use statistics), the lack of validity in burrow count data (Van Horne, this volume), makes statistical analyses suspect.

Number of sampling sites required to show statistical significance for categories was not feasible with the project resources and inherent variation in burrow count estimates. Even with statistical significance, far greater precision has been assigned to habitat

differences identified from burrow counts than with the extensive mark-recapture program of Study 4 (K.P. Burnham, USFWS, pers. commun.). A statistically significant response in burrow counts that differ by 25% does not convey the same, and may even falsely represent, the right population response.

Fifty-four historical transects established in the SRBOPA (excluding the OTA) were sampled in 1982 and 1986-1991 (Yensen et al. 1992, Knick 1990, 1991). The total number of burrows counted on historical sites in 1992 was the highest since 1987 and may represent increased populations of ground squirrels. In addition to the historical transects, results from the random sites indicate that ground squirrel populations were higher in 1992 than in 1991.

Black-tailed Jackrabbits

Jackrabbits have been censused in the Snake River Birds of Prey Area by night spotlight counts using line transect methods since 1977 (Wolfe et al. 1977). Black-tailed jackrabbits are cyclic with approximate 7-12 year intervals between peaks (Johnson and Peek 1984). In the Snake River Birds of Prey Area, densities peaked in 1979 and are again in a high density phase of the cycle. Estimates of jackrabbit densities increased in 1991 from 1989 and 1990 levels. These conclusions differ from 1991 results (Knick 1991) because data from 1977 through 1991 were reanalyzed with program DISTANCE. In addition, different models and criteria for selection (Burnham and Anderson 1992) were used to fit the distribution of sightings.

The differences in estimates of jackrabbit densities relative to the grazing drift fence or OTA are likely due to vegetation gradients rather than actual differences caused by grazing system or military tracking. Regional comparisons should be viewed with caution because no attempt was made to proportionally sample habitats between regions.

■ PLANS FOR NEXT YEAR

Townsend's Ground Squirrels and Habitats

I will sample ground squirrel burrows and habitats at 150 to 200 sites randomly selected throughout the Integration Study Area and the OTA. I will continue to conduct burrow counts on the historical transects and sites established in 1991 and 1992 to define yearly variation in populations and habitats (Fretwell 1972, Southwood 1977, Hanski 1985). All burrow counts will be conducted within a 3-4 week period in mid-May to mid-June to minimize temporal variation. Until greater confidence can be established for burrow counts as indexes of population size, I cannot justify increasing the sampling effort beyond the 1992 level.

Recommendations from Calibration Results.--Results from calibration transects suggested that comparison of burrow counts over a long sampling season is highly biased because of temporal variation in burrow numbers. To avoid subjective model fitting, burrow counts should be conducted within a narrow time frame (3-4 week period) from

mid-May to mid-June. Comparisons between regions, habitats, or land-use practice should be done on a paired sampling basis within a time frame, rather than comparing sites with widely different sample dates.

These recommendations will impose a large demand on personnel time during a short portion of the field season. A 2-person field crew can sample 6-8 transects/day. This would result in approximately 250 transects sampled at 1992 field team levels. The sites would have to be established in advance, and revisited later for vegetation sampling.

Calibration transects should be continued and established in more habitat types. I recommend that transects be sampled weekly, rather than biweekly, to better define the temporal dynamics during the burrow count sampling period.

Temporal and Spatial Analysis of Burrow Count Estimates.--I will expand the analysis of temporal and spatial dynamics using burrow counts as the population index, after considering the validity of the index. If numbers of Townsend's ground squirrels can be related in space and time, then changes in that process can be evaluated for the source of that disruption. One approach to be evaluated will use canonical correspondence analysis (ter Braak 1986) to separate species variation into environmental and spatial partitions (Borcard et al. 1992).

Vegetation and Soils.--Vegetation will be sampled at newly established random sites used for counting burrows of ground squirrels. Because of the need to conduct all burrow counts within a limited period, the sites will need to be revisited to sample

vegetation after the burrow counts are concluded.

The relationship between soils and vegetation will be further examined with 100 samples collected at 1992 study sites and sent to the University of Idaho for analysis. Establishing links between soil variables and vegetation may provide insights into disturbance on vegetation.

Black-tailed Jackrabbits

I will continue spotlight counts to estimate spring densities on historical transects. I will sample each transect twice and add additional routes to increase the area and treatments sampled. I will survey historical and new transects throughout the SRBOPA by spotlight methods (Smith and Nydegger 1985) during December to determine winter jackrabbit densities and distribution.

Habitats will be determined along spotlight transects for jackrabbits from the GIS layer of vegetation for the SRBOPA after an acceptable level of accuracy in the vegetation map is achieved (Knick et al., this volume). The habitat recorded at each jackrabbit sighting will be compared with habitat availability along the transect. I also will examine the potential of relating habitat edge and patchiness to the observations after the vegetation map is produced.

Jackrabbit densities will be contoured for the transects in the SRBOPA by using Dynamic Line Segmentation techniques in ARC/INFO ver. 6.0. Spatial and temporal analysis of contoured densities of jackrabbit densities may permit conclusions that can be related to major influences, such as wildfires, on habitats, or in evaluation of golden eagle (*Aquila chrysaetos*) foraging.

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Use of Satellite Imagery to Delineate Habitats in the Snake River Birds of Prey Area

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Annual Summary

*We revised our habitat classification scheme based on vegetation samples from 1991 and 1992 by Study 5 of the BLM/IDARNG Research Project. The new habitat classification has 26 potential classes based on percent cover of dominant vegetation. All habitat classes are represented in the current vegetation data (range of samples/class: 1-671). The statistical error rate for habitat classification of 2,060 samples was 8.8% and represents the inherent variation in the vegetation. Most errors resulted from classification of medium density shrublands into grasslands, or from grasslands reclassified into disturbance categories. Plant species were not randomly associated; positive associations were winterfat (*Ceratoides lanata*) - spiny hopsage (*Grayia spinosa*) and bud sage (*Artemisia spinescens*) - shadscale (*Atriplex confertifolia*). All 4 negative associations involved Russian thistle (*Salsola iberica*) with cheatgrass (*Bromus tectorum*), Sandberg's bluegrass (*Poa secunda*), bottlebrush squirreltail (*Sitanion hystrix*), and big sagebrush (*Artemisia tridentata*).*

The satellite imagery could not detect differences in percent cover of any single or group of vegetation species. However, the difference vegetation index (DVI), derived from the ratio of TM Bands 4 and 3 distinguished agriculture in the 3 September 1990 image from all other habitat classes. The separation was not as strongly defined in the 11 May 1989 or 30 March 1991 satellite images. Fall imagery may have potential for delineating agriculture areas with crops present from the current year.

Our method for creating the vegetation map from satellite imagery involves a 3-step process. First, agriculture was identified from the DVI ratio for TM bands 4 and 3 in the 3 September 1990 image. Remaining unidentified pixels were then separated into major grassland/shrub groups with a misclassification rate of 20.8% for 709 test sites. Separate groups were then classed into the individual habitat classes with a misclassification rate of 5.7% for the test data (n = 361) in grasslands and 9.3% for shrubs (n = 348). Accuracy of the vegetation map was estimated at 70-80% based on multiplication of probabilities for the grass/shrub division (0.79) and subsequent separation into grassland (0.94) or shrub (0.91) classes.

■ OBJECTIVES

1. To develop a habitat classification scheme for the Snake River Birds of Prey Area.
2. To determine the relationship between vegetation and spectral qualities in Thematic Mapper satellite imagery.
3. To create a vegetation map from satellite imagery for the Snake River Birds of Prey Area.

■ INTRODUCTION

The Global Climate Change Program in the Raptor Research and Technical Assistance Center is developing a vegetation map of the Snake River Birds of Prey Area (SRBOPA) using satellite imagery. This effort (Knick et al. 1991) involves an interaction of field surveys and computer processing in image processing and Geographical Information

Systems (Fig. 1). In this report, we discuss 3 phases of the project. First, we develop the habitat classification for the SRBOPA. The classification scheme is critical because defined habitats must be biologically meaningful and discernable by field personnel as well as by satellite imagery. Second, we report the correlation of vegetation and spectral qualities in the satellite images. Finally, we discuss progress in creating the vegetation map. An additional phase of this study, mapping recent burns from MultiSpectral Scanner satellite imagery, is presented as a separate paper (Kramber, this volume).

Accurate maps of vegetation are essential for studies that relate organisms to spatial elements in their environments. Diverse issues of fire behavior, habitat fragmentation, landscape ecology, reserve design, as well as long-term effects of global climate change all have components dependent on spatial relationship of habitats. Until recently, vegetation maps were derived by interpreting aerial photography or were obtained from

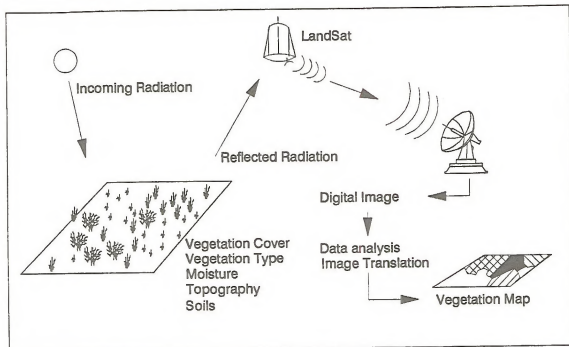


Fig. 1. Pathways in the process of creating a vegetation map from a remote sensing platform.

intensive ground-based efforts. Spatial capabilities of Geographical Information Systems coupled with image processing software now permit creation of habitat maps by interpreting satellite images.

Satellite imagery has potential advantages over more traditional ground-based approaches. Most field studies suffer trade-offs between size of the study area versus sampling resolution, because only a small proportion of the total study area is sampled even with intensive ground-based vegetation measurements. For example, a study of Townsend's ground squirrels (*Spermophilus townsendii*) and habitats in the Snake River Birds of Prey Area will draw conclusions from approximately 800 4-ha sampling sites that represent < 2% of the total study area

(Knick 1990). Satellite imagery potentially permits a fine-grained habitat analyses at a resolution of 25 m for Thematic Mapper satellite imagery over a large area. Modeling spatial and temporal phenomena from satellite imagery also minimizes biases caused by changing personnel or equipment and obviates the need to establish permanent ground markers.

Delineation and analysis of forested regions and agricultural croplands by satellite imagery has been successful and is emerging as a powerful technique to study earth processes (Roughgarden et al. 1991). However, habitats in rangelands and other arid ecosystems are more difficult to delineate because the percent cover of vegetation and photosynthetic material is

relatively low compared to other influences, such as soil reflectance, on spectral quality (Ustin et al. 1985, Tueller 1987). Spectral responses in satellite imagery also are less sensitive to desert vegetation because the relatively simple vegetative structure has minimal influence on reflective and refractive radiation. In this report, we describe our progress in developing the methodology to identify vegetation in Great Basin rangelands by satellite imagery.

• METHODS

Study Area

The Snake River Birds of Prey Area (116 degrees E Long, 43 degrees N Lat) includes approximately 195,325 ha of Great Basin desert rangeland in southwestern Idaho. Once predominantly shrubland, approximately one-half of the shrubland in the SRBOPA has burned since 1975 (Kochert and Pellant 1986). Livestock grazing and military training are the primary land-use activities (Kochert and Pellant 1986). Weather in the SRBOPA is characterized by hot, dry summers and cold winters. Maximum daily temperature has averaged 30-36 C during Jun-Aug and 5-9 C during Dec-Jan at the Swan Falls weather station, within the SRBOPA; annual precipitation at this site averaged 26.9 cm.

Habitat Classification

Vegetation Sampling.--Percent cover of plant species was sampled at randomly located sites within the SRBOPA from 1987 to 1992. Size of the area sampled (the resolution of our vegetation sampling) ranged from 25 x 25 m to 100 x 400 m transects. Cover was sampled by point

frame intercept (Floyd and Anderson 1982) or belt transect (U.S. Dep. Defense 1987). In addition to percent cover of individual species, for each site we determined percent cover for 3 groups: percent total vegetative cover, percent shrub cover, and percent grass cover. Russian thistle was the only annual forb used in our analysis because of yearly fluctuations in other forbs. Each site was located by a Global Positioning System to an accuracy of ± 25 m.

Development of the Habitat

Classification.--We determined the habitat classification with data from the following sources: (1) 200 vegetation surveys in the Orchard Training Area conducted by the Idaho Army National Guard as part of the Land Condition Trend Analysis (Quinney 1990), (2) 44 random locations that were used for ground verification of the 11 May 1989 satellite image (Raptor Research and Technical Assistance Center, unpubl. data), (3) 326 transects from Study 5 during 1990-92 of the BLM/IDARNG Research Project (Knick 1990, 1991, this volume), (4) vegetation surveys on 61 traditional ground squirrel transects (Yensen et al. 1992), and (5) 16 transects for assessment of burns in shadscale habitats (Groves and Steenhof 1988).

All existing vegetation data since 1987, both quantitative and qualitative, were used to identify appropriate vegetation (= habitat) categories or classes. We did not use information collected before 1987 because of potential vegetation changes that could obscure current classifications.

We combined statistical and empirical approaches to deriving habitat classes from the existing vegetation data in an iterative process. The preliminary classification was

developed at the beginning of the BLM/IDARNG Research Project in 1990. First, we subjected 379 existing samples of vegetation data to a cluster analysis (PROC FASTCLUS, SAS Statistical Institute 1988), specifying 14 initial clusters, to identify natural groups of vegetation. Fourteen groups were selected as an appropriate number of initial clusters based on inspection of the data and our estimate of the number of different vegetation types. Distinctness of the resulting classes was confirmed by performing a linear discriminant analysis of the 379 samples (PROC DISCRIM, SAS Statistical Institute 1988), using cluster membership as the classification variable and species coverage values as predictor variables. Finally, we added habitat types not represented in the original samples, but which our field experience indicated were present.

We refined the habitat classification scheme in each subsequent year as additional vegetation surveys, conducted by Study 5 of the BLM/IDARNG Research Project (Knick 1990, 1991, this volume), were added to the pool of habitat data. Refinements in classification were made after comparing vegetation characteristics in misclassified samples with correctly classed categories from a linear discriminant analysis. Values delimiting density categories were determined from visual inspection of the distribution of percent cover values for individual plant species.

Finally, we repeated the linear discriminant analysis on the vegetation data, accepting the reclassified habitats for samples until a misclassification error < 10% was attained. This error rate was a trade-off between

having sufficient number of classes to adequately describe the study area but still maintain a statistical reliability in separating classes. For example, a single habitat, such as desert rangeland, could be classed with 100% statistical reliability but would be of little value in describing vegetation at our scale of investigation. The characteristics of the reclassified habitats helped define the boundaries of our habitat types in the classification. We then wrote a computer program (Turbo Pascal v6.0) to classify samples based on these cover characteristics.

Field Estimation of Habitat Classes.--The ability of field observers to accurately identify habitats was assessed by comparing statistical and field habitat assignments. Each observer ($N = 3-4$) on a Study 5 field team independently classified the site before starting the vegetation surveys at 117 sites. We began these tests beginning in the third week of the field surveys and after each observer was experienced with both plant identification and with our habitat classification scheme. Both observer estimates and statistical classifications assigned a habitat type based on percent cover of vegetation for the 100 x 400 m sites established by Study 5, and represents the scale of this error estimate.

Statistical Analysis for Species Associations.--We tested the pattern of species associations at 116 sites sampled in 1991 for deviations from random by using a log-linear model as the null case (Gilpin and Diamond 1982, Jackson et al. 1992). Our objectives were to determine if species deviated from random associations and to identify significant interactions between species that our classification system should reflect.

The log-linear model (Gilpin and Diamond 1982) is based on binary data consisting of presence/absence for m species. A matrix of species i in row R and sampling sites j in column C was used to determine the total, T , of all species occurrences where $T = \sum R_i = \sum C_j$. The probability of species i occurring at site j is $P_{ij} = R_i C_j / T$ and the probability of finding any 2 species jointly at a site is $P_{ij} P_{kj}$. The expected probability, E , of finding any 2 species in the sample is $E_{ik} = \sum P_{ij} P_{kj}$ and the standard deviation is $SD_{ik} = [\sum P_{ij} P_{kj} (1 - P_{ij} P_{kj})]^{1/2}$. We determined the observed number of species co-occurrences, O_{ik} , from the original matrix of presence/absence data.

We determined the deviation of observed - expected values for $m(m-1)/2$ possible species combinations where $d_{ik} = (O_{ik} - E_{ik})/SD_{ik}$. The distribution of d_{ik} 's was tested for departure from random by comparison with a normal distribution with a mean = 0 and SD = 1 by a Kolmogorov-Smirnov test. Significant species interactions were identified if $d_{ik} > \text{abs}[1.96]$ for a 2-tailed probability test at $\alpha = 0.05$.

Vegetation Indexes and Satellite Imagery

Satellite Imagery.--We used Thematic Mapper satellite images taken on 11 May 1989, 3 September 1990, and 30 March 1991 to maximize differences in vegetation phenology and also increase our ability to separate habitat classes. Pixel size (resolution of the images) was 25 m, and each image consisted of 255 potential shades in each of 7 spectral bands (6 reflective, 1 thermal). Therefore, each pixel in the SRBOPA was represented by 21 spectral variables (3 images, 7 bands/image). We did not use the May 1989 image in areas

where cloud cover obscured the ground in that image. We performed image processing and spatial analyses on the GRASS and ARC/INFO Geographical Information Systems software; statistical analyses were conducted on a PC using the SAS statistical software (SAS Statistical Institute 1988).

Vegetation Indexes.--We evaluated 2 indexes, the PVI (Perpendicular Vegetation Index) (Richardson and Wiegand 1977) and DVI (Difference Vegetation Index), developed from ratioing 2 bands for potential relationship with vegetation characteristics (Ustin et al. 1985). We determined the PVI and DVI for 2 separate ratios of spectral bands (TM4/TM3 and TM7/TM5). Ratios combine multiple bands into a single number that allows the contribution of a factor to be isolated from the interplay of relative attributes of each single band (Maxwell 1976). The PVI and DVI indexes emphasize the relationship of an observed value to a baseline that represents soil background. These indexes were sensitive to vegetation biomass in the TM4/TM3 ratio and to canopy water in the TM7/TM5 ratio (Ustin et al. 1985).

To establish the diagonal in each ratio that represented the soil baseline (Fig. 2), we selected 50 non-vegetated sites in the study area that covered the spectrum of background reflectance (canyon walls, roads, and railroads). The linear regression for the line was highly significant in both TM4/3 ($F = 1,429.86$, 1,48 df, $P < 0.001$, $r^2 = 0.97$) and TM7/5 ($F = 2,729.13$, 1,48 df, $P < 0.001$, $r^2 = 0.98$) ratios in the 3 September 1990 image. The relationship was less significant in the 11 May 1989 and 30 March 1990 images. The PVI was the distance from the point to the perpendicular intercept with the soil baseline diagonal, and

the DVI was the difference between predicted value on the diagonal and observed value ($\hat{y} - y$) (Fig. 2).

Statistical Analysis.--We developed a spatial data base that consisted of percent vegetation cover from the field surveys and spectral values from a 3 September 1990 satellite image by overlaying the site locations with the satellite image in the GIS. We determined direct relationships of vegetation characteristics to spectral value or index in the satellite image by linear regression (Sokal and Rohlf 1981). Multiple regressions of percent vegetation cover with TM bands were not performed because of the high degree of covariance within the TM bands. To overcome this problem, we used principal components analysis (Morrison 1976) to extract independent, orthogonal components from the TM data. We then conducted single and multiple regressions of percent vegetation cover against the resulting principal axes in the image dataset. Multiple regression of vegetation cover with component axes is statistically valid because the original TM band data are reduced in the ordination to uncorrelated axes (Jensen and Waltz 1979).

Although the 2 procedures were somewhat redundant, each had a different emphasis. The regression models between vegetation and spectral values in the TM bands emphasized a direct linear relationship. With principal components analysis, the regression of percent vegetation cover was conducted against the primary axes of variation contained within the set of TM band spectral values.

Vegetation Mapping from Satellite Imagery

We developed the vegetation map from satellite imagery iteratively, with continual upgrades of data sets as more information was collected (Fig. 3). The habitat classification, defining the vegetation patterns, was evaluated and refined each year. Current year's vegetation samples were first used as test data to assess the error in the ability of the images to define habitats. The vegetation data were then added to the existing pool of vegetation data for re-evaluation of the habitat classification. The most recent (and complete) set of vegetation data then defined spectral qualities of habitats at known locations and was used to develop the discriminant function to classify unknown pixels.

We determined spectral signatures, consisting of all TM band values, for each habitat class from a training set of 1,493 points with both vegetation and locational information. Location of each site was established by a Global Positioning System with an accuracy of < 25 m. Vegetation sites were overlaid with the satellite imagery, and additional points were selected in water ($n = 11$), agriculture ($n = 12$), fallow ($n = 13$) fields, or on roadways ($n = 22$). Band values from each image were then output for each site to develop the multivariate function of spectral data that described each habitat type. Only the 3 September 1990 and 30 March 1991 satellite images were used to develop the vegetation map.

Image Interpretation and Development of the Habitat Map.--We used a hierarchical procedure to classify the satellite image into habitat types. First, we identified agriculture/fallow pixels by distance of the

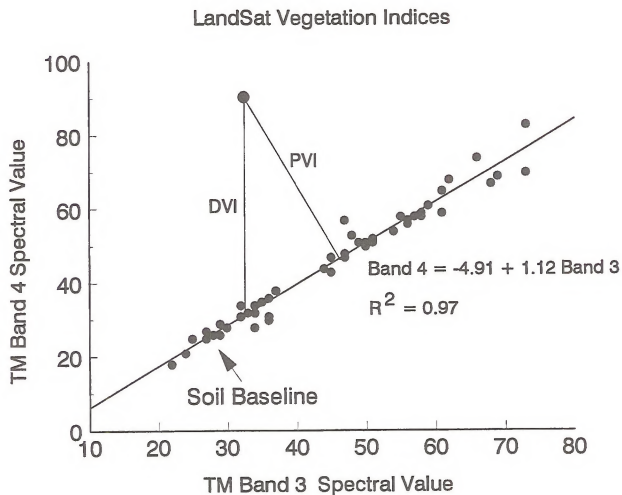


Fig. 2. Relationship of PVI and DVI indexes to the diagonal soil baseline for the ratio of TM Band 4 and TM Band 3.

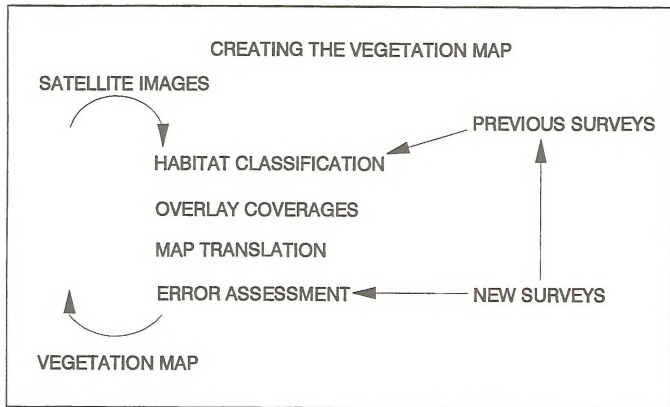


Fig. 3. Flow chart for the iterative process of developing the vegetation map from satellite imagery for the Snake River Birds of Prey Area.

residual (DVI index) from the baseline of bare ground in the ratio developed from TM bands 4 and 3 in the 3 September 1990 image. Second, we separated the remaining unidentified pixels into grass or shrub categories using a nonparametric method to develop a quadratic discriminant function. A multivariate normal distribution was used to describe the distribution within each class identified in the training set (PROC DISCRIM, SAS Statistical Institute 1988). We used the set of known habitats and locations to develop the discriminant functions used to classify the remaining

unknown pixels in the image. Finally, we classified within grass or shrub groups into respective final classes in the habitat classification. Accuracy of the images to discriminate our habitat classes was evaluated at the second and final steps from the posterior probability estimates developed in the quadratic discriminant function for both calibration and test data. The nonparametric method of deriving a quadratic discriminant function was more appropriate than a linear approach because of the distribution of the spectral data and differences within group variances.

Error Assessment of the Vegetation Map.--Two sources of error were involved in creating the vegetation map: (1) the error in classifying vegetation, and (2) the error in the imagery used to classify our habitat classes. We estimated error rates in our habitat classification with results from 2,060 sites sampled for percent cover of vegetation between 1987 and 1992. The statistical error in classifying habitats was determined by posterior error rates in the discriminant analysis after each sample was assigned a habitat by using the PASCAL computer program and was a measure of the inherent variation in the vegetation. We also used posterior error rates from the discriminant analysis to determine the error in the imagery used to discriminate our habitat classes. This error represented the spectral variation in the image. Thus, the probability of correct translation of spectral reflectance information for a pixel into a habitat class was the multiplication of these 2 independent probabilities.

We also determined classification accuracy from 707 points of known habitat class derived from 170 vegetation surveys by Study 5 of the BLM/IDARNG randomly located throughout the study area. Each 100 x 400 m transect in the original survey was sampled by 7 5-m sections within 50-m laterals from the main transect (Knick 1991). Thus, each 5-m section provided vegetation information at a precise location for overlay with a 25 x 25-m pixel on the satellite image after the initial transect was located by Global Positioning System. These points with a known habitat class were independently classified by our hierarchical method using a calibration set of 786 samples from previous surveys and error rates for the test data determined from the

posterior errors in classification at both stages of the classification process.

■ RESULTS

Habitat Classification

Our habitat classification scheme had 26 potential habitats based on percent cover of dominant vegetation (Table 1). Number of samples in our vegetation surveys representing these habitat classes ranged from 1-671 (Table 2). The distribution of plant cover values, intended to define natural breakpoints for density categories, was continuous in all species (Fig. 4). We then adjusted the breakpoints for categories after inspection of reclassified habitats in the discriminant analysis. Statistical misclassification rates remained similar despite changing percent cover of breakpoints. Therefore, we assigned percent cover values for medium (5 - 25%), and high (> 25%) shrub density based on our assumption that field personnel could identify these categories in the field.

The statistical error in habitat classification, estimated by posterior error probabilities in the linear discriminant analysis, was 8.8% (26 habitat classes, $n = 2,060$). Most classification errors were caused by medium density shrublands (class 1B) being reclassified into grasslands (class 2A or 2A) and accounted for 52% (72 of 137) of the observations misclassified between major groups (Table 3). Grasslands reclassified into disturbed categories (class 1D) represented an additional 18% of the misclassified observations (Table 3).

Ordination by canonical discriminant analysis further emphasized relationships

Table 1. Habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area, 1987-92. Mean cover values of vegetation for each class are given in Table 2.

1. Shrublands

A. High Density Shrub (Cover > 25%)

1. Sagebrush
2. Shadscale
3. Winterfat
4. Greasewood
5. Budsage
6. Nuttall's saltbush
7. green rabbitbrush
8. gray rabbitbrush

B. Medium Density Shrub (Cover > 5 and < 25%)

1. Sagebrush
2. Shadscale
3. Winterfat
4. Greasewood
5. Budsage
6. Nuttall's saltbush
7. green rabbitbrush
8. gray rabbitbrush

1. D. High disturbance regions

1. Russian thistle > 15%, cheatgrass > 25%, native grass > 25%
2. Russian thistle > 15%, cheatgrass > 25%, native grass < 25%
3. Russian thistle 15-35%, cheatgrass < 25%, native grass < 25%
4. Russian thistle > 35%, cheatgrass < 25%, native grass < 25%
5. Russian thistle > 35%, cheatgrass < 25%, native grass > 25%
6. Russian thistle 15-35%, cheatgrass < 25%, native grass < 25%

2. Grasslands

A. Low disturbance

1. native perennial grasses > 25%, cheatgrass < 25%
2. native perennial grasses < 25%, cheatgrass < 25%

B. High disturbance

1. Cheatgrass > 25%, native grasses < 25%
 2. Cheatgrass < 25%, native grasses < 25%
-

Table 2. Average percent cover of vegetation and number of samples for habitat classes in the Snake River Birds of Prey Area. Habitat classes are described in Table 1. Native grasses (NTGS) are the sum of cover values for Sandberg's bluegrass, bottlebrush squirreltail, and six-weeks fescue.

Habitat Class	Plant Species ^a											
	N	ARTR	ATCO	CELA	SAVE	ATNU	ARSP	CHNA	CHVI	NTGS	B RTE	SAIB
1A1	222	39								9	7	
1A2	23		33	1			2			3	5	2
1A3	35	1	2	33			1			14	1	1
1A4	1				40							
1A5	2		3			28					10	
1A6	2		2	9			20			2		
1A7	1	1						21		9	7	4
1A8	1								23	2		
1B1	240	15								8	12	1
1B2	90		12					1		3	4	4
1B3	91	1		16			1			8	1	1
1B4	2				15					3	1	13
1B5	10	2				6				18	10	4
1B6	10		3	3			11			9	1	1
1B7	4							10		4	16	4
1B8	10								10	18	18	2
1D1	1	1								42	32	16
1D2	26									8	38	25
1D3	184									5	2	23
1D4	53									3	4	49
1D5	16									36	1	43
1D6	42									43	3	24
2A1	120									37	3	3
2A2	671									7	4	3
2B1	3									36	29	1
2B2	200									5	48	2

^a/

ARTR = big sagebrush ATCO = shadscale CELA = winterfat SAVE = greasewood

ATNU = Nuttall's saltbush ARSP = bud sage CHNA = gray rabbitbrush

CHVI = green rabbitbrush NTGS = native grasses B RTE = cheatgrass

SAIB = Russian thistle

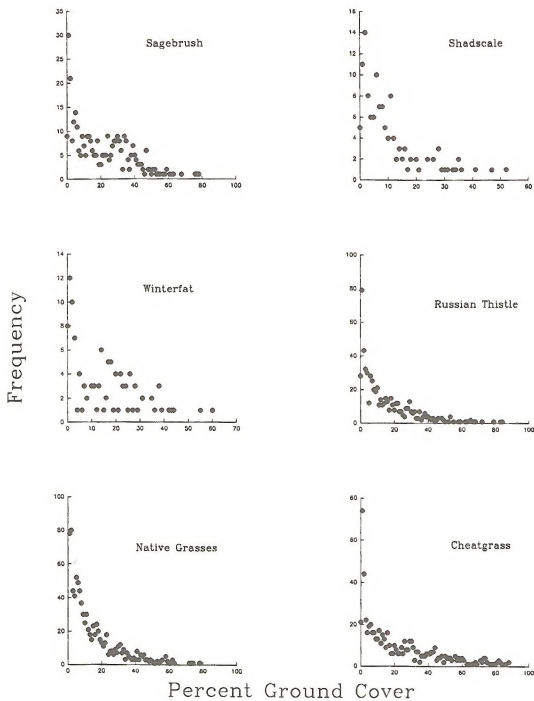


Fig. 4. Distribution of percent cover values for dominant plant species used in the habitat classification scheme.

Table 3. Error matrix for major categories of the habitat classification. Errors represent number of misclassified observations in a linear discriminant analysis of 2,060 samples and 26 habitat classes. Habitats are described in Tables 1 and 2.

Sample Habitat Class	Reclassified Habitat				Total
	1A	1B	1D	2A/2B	
1A	268	19	0	0	287
1B	7	357	6	72	442
1D	0	1	317	4	322
2A/2B	0	3	25	981	1,009
TOTAL	275	380	348	1,057	2,060

between the habitat classes (Fig. 5). Cumulative proportion of the variance explained was 0.69 for the first axis, and 0.90 for the first 5 axes (Table 4). Although class means were separated in statistical space, the relationship between classes 1B and grassland classes (2A/2B) indicated that separation of these groups was not distinct (Fig. 5).

Field personnel were less able to correctly classify habitats (Table 5) than the statistical determination. Most errors resulted from incorrectly estimating percent cover (e.g., between 1A and 1B categories) or from a wrong assignment of dominant vegetation.

Plant species in 116 samples from the 1991 vegetation surveys were not randomly associated. The log-linear model of expected to observed plant species associations was significantly different from a normal distribution (Kolmogorov-Smirnov $D = 0.269$, $P = 0.007$) and was skewed toward negative associations (Fig. 6).

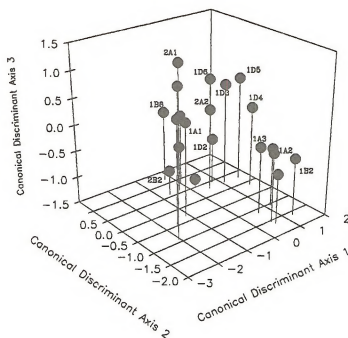
Winterfat was positively associated with spiny hopsage, and bud sage was found with shadscale more than expected. All negative associations involved Russian thistle (Fig. 6).

Vegetation Indexes

We used the sample of vegetation at 793 sites randomly located sites throughout the SRBOPA from 1987 through 1991 for analysis of percent vegetation cover with satellite band information. The dominant shrubs sampled were big sagebrush winterfat and shadscale. The primary native grasses were Sandberg's bluegrass and bottlebrush squirreltail, and cheatgrass was the major exotic grass. Russian thistle was the dominant exotic forb sampled (Table 6).

Almost all regressions of vegetation cover for both individual species and groups were significant ($P < 0.05$, 1,792 df). However, only 11 regressions accounted for $> 10\%$ (r^2) of the variation in the vegetation data (Table 7). Vegetation cover was never significantly

A.



B.

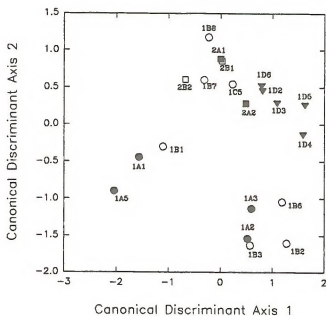


Fig. 5. Primary axes in canonical discriminant analysis of class means for habitats sampled in the Snake River Birds of Prey Area.

Table 4. Canonical discriminant analysis of habitat class means for 2,039 vegetation samples. Habitat classes were represented by 6 - 671 samples; habitats with < 5 observations were not included in the analysis.

Canonical Discriminant Axis	Eigenvalue	Difference	Proportion	Cumulative
1	10.4009	1.5132	0.2635	0.2635
2	8.8877	1.9237	0.2252	0.4887
3	6.9640	2.6884	0.1764	0.6652
4	4.2756	0.6270	0.1083	0.7735
5	3.6486	1.7761	0.0924	0.8659
6	1.8725	0.3073	0.0474	0.9134
7	1.5652	0.5511	0.0397	0.9530

Table 5. Error matrix for estimates of habitat class by field personnel and actual habitat determined from percent cover of plant species. Underlined entries represent cells with correct classification.

Field Est.	Actual Habitat Class										TOTAL
	1A1	1B1	1B2	1B3	1B8	1D3	1D4	2A1	2A2	2B2	
1A1	<u>23</u>	47		2					1		73
1A2			1	2					7		10
1A3				8					1		9
1A6				1							1
1A8					3						3
1B1		<u>17</u>							7	3	27
1B2			<u>12</u>	1					14		27
1B3				<u>4</u>							4
1B5									1		1
1B6			2						1		3
1B8					<u>6</u>						6
1D1									4		4
1D2									2		2
1D3						6			18		24
1D4						25	<u>3</u>		2		30
1D5		1				7			4		12
1D6		1				2		1	12		16
2A1		5						<u>11</u>	23		39
2A2		3				1			<u>34</u>		38
2B1								1	5	2	8
2B2			2						19	<u>5</u>	26
Total	23	76	15	18	9	41	3	13	155	10	363

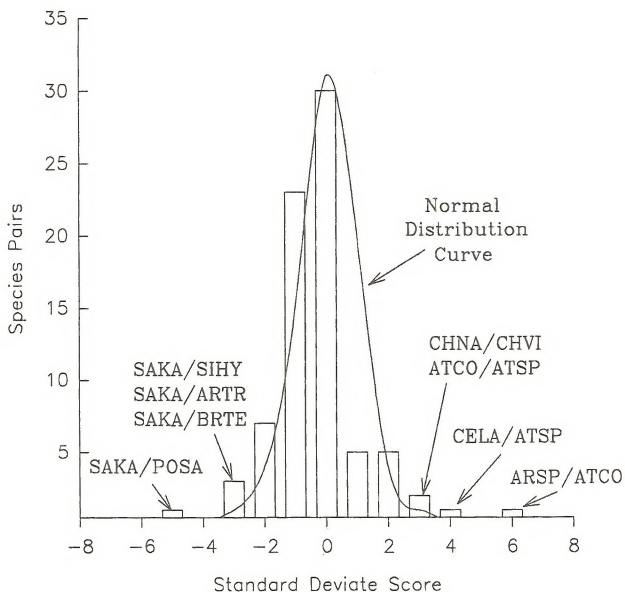


Fig. 6. Frequency of observed standard deviate scores from a log-linear model of species associations relative to expected number in a normal distribution.

Table 6. Dominant vegetation species sampled at 793 randomly located sites throughout the Snake River Birds of Prey Area. Mean and SE were determined only for nonzero sites.

Plant Species	No. Sites	Percent Cover		Maximum
		Mean	(SE)	
<u>Shrubs</u>				
Big Sagebrush	249	24.1	1.1	78.3
Shadscale	85	12.3	1.2	51.5
Winterfat	71	18.7	0.8	59.7
% Shrub Cover	406	24.8	0.8	78.3
<u>Grasses</u>				
Sandberg's Bluegrass	573	14.1	0.3	57.7
Cheatgrass	466	25.5	1.0	87.8
Bottlebrush Squirreltail	389	5.0	0.3	60.0
% Grass Cover	775	37.7	0.9	95.0
<u>Forb</u>				
Russian Thistle	438	15.9	0.3	83.9
% TOTAL VEGETATION COVER	793	48.2	0.8	95.0

Table 7. R^2 values for significant correlations between vegetation cover with spectral values of individual Thematic Mapper Bands or indexes of band ratios. A 3 September 1990 image was used for the analysis. Only regressions that explained > 10% (r^2) are shown.

Vegetation	TM Band Number			TM Band 7/5	
	1	2	4	DVI	PVI
Big Sagebrush	0.11	0.13	0.18		
Russian Thistle			0.13		
Cheatgrass		0.11	0.14	0.12	0.12
% Cover Grass	0.11	0.12	0.12		

related to TM Bands 3, 5, 6 (thermal band), and 7. Likewise, vegetation cover was not significantly correlated with the PVI and DVI indexes derived from the ratio of TM Bands 4/3.

The DVI for the ratio of TM Bands 4/3 distinguished agriculture from the remaining habitats in the 3 September 1990 image (Fig. 7). The DVI for agriculture fields averaged 96.0 (range 72.3-115.0, $N = 12$) compared to 21.3 (range 0-42.3, $N = 866$) for other habitats. The DVI or PVI could not separate agriculture or other habitats in the 11 May 1989 or 30 March 1991 satellite images. The first axis in the principal components analysis accounted for 64% of the variation in spectral values for the 7 TM bands at sites where vegetation was sampled (Table 8). Subsequent axes explained $\leq 15\%$ of the total variation; 97% of the total variation was contained in the first 4 axes.

Regression of vegetation cover with single component axes accounted for $< 10\%$ (r^2) of the variation. For multiple regressions of vegetation cover with all 7 axes, big sagebrush, Russian thistle, cheatgrass, and percent cover of vegetation groups were significantly correlated (Table 9). In each case, $< 25\%$ of the variation was accounted for in vegetation coverage values.

Vegetation Mapping

We used a calibration set from 786 samples with known habitat and spectral data to develop the quadratic discriminant function for classifying 709 samples in test data of known habitats into major grassland (classes 1D, 2A, and 2B) or shrub groups (classes 1A and 1B) based on spectral information from the 3 September 1990 and 30 March 1991 images. The posterior error rate within the

calibration data was 9.1%. The misclassification rate for the test data was 20.8% and represents our error in distinguishing between grasslands and shrubs (Table 10).

Separate grassland and shrub groups were then classed into our habitat categories using the function developed from the calibration set for that group. For grasslands, the calibration data ($n = 466$, 5 habitats represented) had a posterior error rate of 6.0%. The misclassification rate for the test data ($n = 361$) was 5.7% and represents our error in classifying grassland habitats after the major grassland/shrub division was made. However, this estimate is not a true error rate because most errors were shrub sites that were misclassified in the previous step (Table 11).

The calibration data for shrubs ($n = 241$, 8 habitats represented) had a posterior error rate of 7.9%. The misclassification rate for the test data ($n = 348$) was 9.3% and represents our error in separating observations into specific shrub habitats once the grassland/shrub division was made. Again, this error is not a true estimate because most errors were grassland sites that were misclassified in the previous step (Table 12).

Our overall accuracy, determined from 709 test points, in developing the vegetation map using this method is between 70-80% based on multiplication of the initial probability (0.79) and subsequent probabilities for grasslands (0.94) and shrubs (0.91). However, these are not independent events because the error within the second step includes misclassification errors from the first division into major grassland/shrub classes. Therefore, this estimate is a lower bound.

Landsat Vegetation Indices

Habitat Means

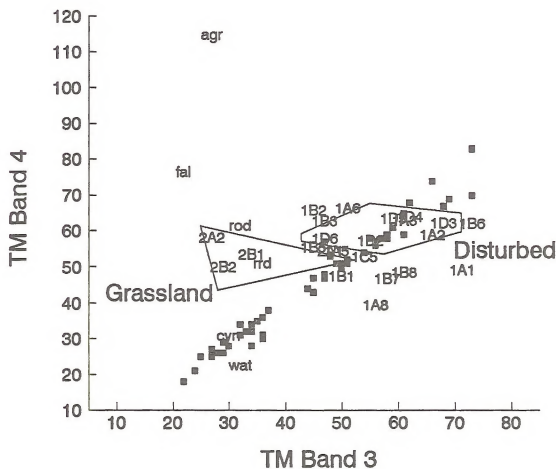


Fig. 7. Relationship of mean residual value for habitat classes in a 3 September 1990 satellite image using a ratio of TM Bands 4/3 to develop the regression for soils background. Current year's agriculture regions were separated from other habitats by this relationship.

Table 8. Principal components analysis of spectral values for 7 Thematic Mapper Bands in a 3 September 1990 image at locations where vegetation was sampled in the Snake River Birds of Prey Area.

	Principal Component Axis						
	1	2	3	4	5	6	7
Eigenvalue	4.49	1.05	0.84	0.44	0.13	0.04	0.01
Tot. Var. (%)	0.64	0.15	0.12	0.06	0.02	0.01	0.00
Cum. Var. (%)	0.64	0.79	0.91	0.97	0.99	1.00	1.00

Table 9. Multiple regression analysis of vegetation cover with principal component axes of spectral values from a 3 September 1990 Thematic Mapper satellite image. Only significant regressions are shown.

Vegetation Component	Mult. r^2	$F_{7,785}$	P
Big Sagebrush	0.21	19.85	0.0001
Russian Thistle	0.18	25.73	0.0001
Cheatgrass	0.25	38.05	0.0001
% Cover Shrub	0.14	19.85	0.0001
% Cover Grass	0.21	31.76	0.0001
% Total Cover	0.10	13.90	0.0001

Table 10. Error matrix of observations classed into grass or shrub categories at the first step of creating a vegetation map from satellite imagery. The calibration set consisted of 786 observations and had a posterior error rate of 9.13%. The test data consisted of 709 observations with known habitats. Underlined entries represent correctly classified observations.

Known Habitat Group	Classified Habitat Group		
	Grass	Shrub	Total
Grass	<u>336</u>	131	467
Shrub	25	<u>217</u>	242
Total	361	348	709

Table 11. Error matrix of observations classed into individual disturbance or grassland classes after separation into grass or shrub groups. The calibration set consisted of 466 observations and had a posterior error rate of 6.01%. The test data consisted of 361 observations with known habitats. Underlined entries represent correctly classified observations.

Known Habitat Class	Classified Habitat Group					
	1D3	1D4	2A1	2A2	2B2	Total
1A1				1	1	2
1B1	1			10	4	15
1B2	1			4		5
1B3				1		1
1B5				2		2
1D3	<u>41</u>	1				42
1D4		<u>6</u>				6
1D6	1					1
2A1			<u>35</u>			35
2A2	3		12	<u>202</u>	3	220
2B2					<u>32</u>	32
Total	47	7	47	220	40	361

Table 12. Error matrix of observations classed into individual shrub classes after separation into grass or shrub groups. The calibration set consisted of 241 observations and had a posterior error rate of 7.88%. The test data consisted of 348 observations with known habitats. Underlined entries represent correctly classified observations.

Known Habitat Class	Classified Habitat Group								Total
	1A1	1A2	1A3	1B1	1B2	1B3	1B5	1B6	
1A1	<u>41</u>								41
1A2		<u>7</u>							7
1A3			<u>9</u>						9
1A4				1					1
1B1	13			<u>60</u>			2		75
1B2		2			<u>32</u>				34
1B3			2			<u>44</u>			46
1B5							<u>1</u>		1
1B6								<u>3</u>	3
1D3				9	8	9			26
1D4				3					3
2A1	3			3	2	2			10
2A2	18			34	15	18			85
2B2				4	1	2			7
Total	75	9	11	114	58	77	1	3	348

DISCUSSION

Habitat Classification

Classification of vegetation assemblages into discrete communities is a fundamental process in many ecological studies to identify pattern or structure in data (Gauch 1982). Interactions of species both within and external to an ecological community form the framework of a variety of ecological investigations (e.g., Cornell and Lawton 1992). In addition, community

organization and distribution within a landscape are important descriptors in interpretation of short-term land use practices as well as long-term influence of global climatic changes (Burke and Kiester 1990). Therefore, identification of communities is a nontrivial process that can affect interpretation of these studies and our understanding of animal and habitat relationships.

Vegetation classifications should respond to several criteria. First, discrete communities

should represent repeatable assemblages within the sample. The communities should be statistically distinguishable as well as readily recognizable by field personnel. Ideally, the classification should be robust with respect to scale of investigation. The classification also should represent major gradients in environmental variation.

Our classification scheme consisted of statistically distinct habitat categories but was not accurately estimated in the field by trained observers. Scale likely contributed to many of the errors. Although our habitat classification was designed for the resolution of the satellite image (25 m), our field tests were conducted at the scale of transects in Study 5 (100 x 400 m). Future tests of ability to estimate habitats by field personnel should be conducted at the 25-m resolution of the satellite image.

Inclusion of a separate category for disturbed sites is supported by observed patterns in the vegetation community. The log-linear model suggested that Russian thistle was negatively associated with big sagebrush, Sandberg's bluegrass, bottlebrush squirreltail, and cheatgrass. Except for cheatgrass, all other species negatively associated with Russian thistle are plants found in nondisturbed sites. In addition, analysis by detrended correspondence analysis (ter Braak 1988) demonstrated a strong disturbance gradient responsible for variation in the vegetation data (Rotenberry and Knick, in prep).

Vegetation Indexes and Satellite Imagery

Sensing of the environment from remote platforms is an important tool for applications that include determining productivity of croplands and forests

(Wardley and Curran 1984, Running et al. 1989) and assessing habitat availability for the conservation of wildlife (Hodgson et al. 1988, Robertson et al. 1990, Shaw and Atkinson 1990). Models of habitat changes resulting from global climate changes (Schlesinger et al. 1990) predict significant changes in vegetation communities in areas like the SRBOPA because of its mid-latitude location and semi-arid ecosystem. Understanding potential responses of habitats to changes in global climate also are principal concerns in world environmental agendas (Committee on Earth and Environmental Sciences 1991, Lubchencho et al. 1991).

We investigated possible correlations between Thematic Mapper satellite imagery and vegetation cover for the SRBOPA. Strong relationships would permit mapping of the vegetative component and also assessment of rate of change for that component from analysis of future satellite images (Price et al. 1992). Although similar work in forested regions has been successful (Hall et al. 1991), remote sensing of arid ecosystems has been more ambiguous (Ustin et al. 1985, Tueller 1987).

Our lack of strong correlations of vegetation cover with TM bands, band ratios, or principal component axes was likely due to several factors related to desert ecosystems. First, percent cover of vegetation is a minor component of the land surface viewed by the satellite. In the SRBOPA, mean total cover of vegetation was < 50% of the surface area. Soils, cryptogam cover, and standing dead vegetation or ground litter all influence the satellite image (Tueller 1987). Second, indexes that remove the influence of background soils and are sensitive to water or live vegetation (Ustin et al. 1985) are less

affected by senescent vegetation in late summer or autumn images. However, the 3 September 1990 image strongly separated agricultural regions with green vegetation and may provide an important technique for assessing current year's agriculture regions.

Vegetation Mapping

Mapping vegetation in desert rangelands from interpretation of satellite imagery has not been as successful as in forested or agricultural regions (Price et al. 1992) because sparse vegetative cover in deserts contribute little to the reflectivity perceived by the satellite (Tueller 1987). In addition to challenges created by desert environs, accuracy in creating a vegetation map depends on development of a habitat classification that has distinct categories both in field data and in the image. The most consistent error, separation of lower density shrubs (cover < 15%) and grasslands, was present in both our habitat classification and image interpretation. Once the initial separation into grassland/shrub was determined, subsequent separation into individual habitat classes was relatively accurate (accuracy rate: 91% shrubs; 94% grasslands).

Our current accuracy in creating a vegetation map, (70-80%) determined from 709 verification points, is similar to other published research (79-92% grasslands, chaparral, forest: Davis and Dozier 1990; 70% desert rangelands: Price et al. 1992). Our project benefits from greater numbers of field samples and with further investigation, we likely can improve the map accuracy.

■ PLANS FOR NEXT YEAR

We will continue to improve the habitat

classification as new data become available from Study 5 of the BLM/IDARNG Research Project. In addition, we will include surveys at sites outside the Integration Study Area in our habitat classification and in creating a vegetation map for the SRBOPA.

We will try to improve the accuracy of the current vegetation map by examining the characteristics of misclassified observations. Alternate hierarchies will be examined for possible improvement in classification accuracy. We expect continued improvement as more vegetation and location data become available to better define the spectral signatures of habitat. In addition, we will try to sample habitats not currently represented in the calibration to increase the number of habitats that can be classified. The larger samples may permit a regional approach and should further improve the accuracy because spatial variation will be minimized.

We will investigate additional fall images for potential to determine agriculture regions with crops for the current year. Identification of agriculture regions is important because Townsend's ground squirrels were locally abundant (Knick, this volume) and prairie falcons (*Falco mexicanus*) also hunted in these regions (Marzluff et al., this volume; Strickler et al., this volume) during the drought of 1992.

We will use the vegetation map for analysis of raptor foraging and prey abundance. In addition, we will examine landscape patterns, such as fractal dimensions (Milne 1988, 1992; Palmer 1992), to explain distribution and abundance of shrubsteppe passerine birds. Relationship of other species to landscape patterns also will be

analyzed when data are available. Studies of landscape patterns offer potential for determining the impact of land-use practices on habitats, as well as insights into the scale at which species respond to their habitats (Wiens 1989).

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Integration Activities for the BLM/IDARNG Project - 1992

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Annual Summary

Principal accomplishments of the 1992 Research Project Integration effort included finalizing and implementing a protocol for constructing a habitat base map from satellite imagery, review of 1992 annual reports and 1993 study plans for each component study, and organizing a Project Integration Workshop.

■ OBJECTIVES

1. Provide coordination and quality control for the overall research project.
2. Develop a conceptual model that relates the impacts under study (military activities, grazing, and fire) to trophic level relationships (soils/vegetation, prey, raptors).
3. Develop and maintain the Digitized Resource Data Base Map throughout the course of the overall research project, and use it to support the field effort.
4. Provide support for analysis and preparation of documents concerning impact analysis, management, and monitoring of the SRBOPA consistent with the results of the research.

■ MAJOR ACCOMPLISHMENTS

Assistance in achieving the following accomplishments was provided by the staff of the Raptor Research and Technical Assistance Center of the Bureau of Land Management, particularly Steven Knick, Michael Kochert, Karen Steenhof, and Thomas Zarriello.

1. We finalized and implemented a new protocol for producing a habitat/vegetation map from satellite imagery (Knick et al., this volume). We performed a supervised classification of the original raw spectral data for Spring 1989 and Fall 1989 images using nonparametric, nonlinear discriminant function analysis of 26 habitat classes. The resulting function accurately classified over 80% of a group of independent vegetation samples, and we expect that final map accuracy will exceed 90%.
2. Draft 1992 annual reports were reviewed for research continuity, appropriateness of analytical techniques, and possible data integration problems. Problems identified in study details or direction were corrected, and these corrections were incorporated into the revised annual reports that appear in this volume.
3. Draft 1993 study plans were reviewed for completeness, incorporation of any necessary changes, and possible conflicts among studies. Revised versions of these plans will appear as addenda to the original study plans in the 15 January 1991 Research Plan to Assess the Impacts of Habitat Alteration in the Snake River Birds of Prey Area.
4. A project integration workshop was held in Boise on 17-19 November 1992. Investigators reported on their progress in meeting study objectives and in answering their specific study questions. Each principal investigator, with assistance from workshop participants, identified areas where problems had arisen in answering study questions, and all attempted to provide recommendations for solving those problems. Workshop participants identified conceptual and analytical approaches to answering each of the 10 major project research questions, and discussed the general form a quantitative model integrating habitat, prey, and raptors might take. Several committees were formed to resolve issues for which there was insufficient time to address at the workshop.

■ PLANS FOR NEXT YEAR

1. We will continue to provide coordination and quality control in consultation with component study principal investigators and the Technical Advisory and Review Panel. This will include reviews of 1993 component study annual reports and 1994 study plans. We will also hold another integration workshop, nominally around 15 November 1993.
2. We will begin developing an overall integration model, incorporating as its basis the conceptual system model outlined in the Research Plan. Such a model will likely have 4 main elements: (1) vegetation/habitat map of SRBOPA; (2) prey metapopulation submodel; (3) raptor foraging submodel; and (4) raptor

population dynamics submodel. Inputs to the model would include spatial patterns of vegetation, weather patterns, initial distribution of prey, and locations of any simulated disturbances. Outputs would include the spatial pattern and annual dynamics of prey populations, and population abundances and rates of change for raptor populations. Alteration of inputs would permit the evaluation of alternative management scenarios. The lead for overall model development would lie with the Integration staff and subcontractors as appropriate, with major input and possibly submodel construction by study principal investigators (e.g., Study 4 for TGS).

3. We will continue to develop the Digitized Resource Data Base Map by adding new information as it becomes available from component studies. Additionally, we will complete development of the vegetation/habitat type map from satellite imagery.
4. We will continue to provide support for analysis and preparation of annual reports, study plans, and other documents. In addition, we will assist committees formed at the 1992 Project Integration Workshop in completing their tasks. These tasks include (a) determining appropriate authorship of articles resulting from project research; (b) analyzing implications of statistical non-significance for future management recommendations; (c) follow-up monitoring of *Lepidium* damage; (d) collection and use of weather data; (e) improving resolution of the fate of bench nests; (f) switching measurers between Studies 2 and 3; and (g) media relations and project promotion.
5. We will develop a common database, drawing on the experience of other large scale multi-researcher efforts (e.g., INEL, NSF-LTER's, and DOD-NERP's).
6. We will coordinate a March 1993 meeting among the Management Oversight Group, BLM and IDARNG managers, and Project principal investigators, to provide a mid-project briefing on the status of the research. Project PI's will provide managers with the form that management recommendations will likely take, and solicit suggestions from managers on how such recommendations should be presented.
7. We will form an Integration Team and identify personnel to be associated with each major component of the foregoing integration activities. Team members will meet as needed throughout the year to develop quantitative analyses for the research questions they are to address.
8. We propose to develop a map detailing the fire history of SRBOPA (including the OTA) since the early 1970's using satellite imagery. This burn map will be superimposed on current and previous (i.e., 1979) vegetation maps to develop a history of vegetation change.



PRAIRIE FALCON POST-FLEDGING MORTALITY

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ANNUAL SUMMARY

We instrumented 78 prairie falcon (*Falco mexicanus*) nestlings from 19 broods with 6-g, tarsal-mounted radio transmitters and monitored their survival until they dispersed from the natal territory. Overall, 28% ($n = 22$) of fledged falcons died before dispersal (mean mortality age = 41 days, range = 32.5-60.5 days). Predation by great-horned owls (*Bubo virginianus*) and golden eagles (*Aquila chrysaetos*) accounted for 36.3% of the mortality and ectoparasite infestations were implicated in 18.2% of the mortality. We could not determine the causes of 45.5% of all mortality because carcasses were scavenged and/or decomposed. Parental attendance (% time spent in the territory) and prey delivery rates (prey items delivered to the nest per hr) during late brood rearing ($n = 11$ broods) were not correlated with post-fledging mortality. Broods that hatched late in the season experienced significantly higher mortality ($P = 0.03$) than broods that hatched early in the season. Survivorship was not correlated with nestling weight or brood size.

■ INTRODUCTION

The activities of birds after they fledge from their nest is one of the poorest known portions of avian life history (Beske 1982, Johnson 1986, Konrad and Gilmer 1986). Most studies of breeding biology stop at

fledging because fledglings are mobile and difficult to follow. However, fledglings are often still dependent upon their parents for food and vigilance, and extremely vulnerable to predators, starvation, and accidents as they learn to perfect their flying skills and fend for themselves (Cade 1960). Mortality

is therefore likely to be high and likely to go unnoticed at this time, and we need a better understanding of its magnitude and factors affecting it if we are to fully understand a population's dynamics.

▪ OBJECTIVES

1. To determine the magnitude and causes of post-fledging mortality.
2. To determine if nestling weight, parental behavior, hatch date, and brood size influence post-fledging mortality.

▪ METHODS

Territory Selection

We selected 20 prairie falcon nesting territories being studied by the BLM/IDARNG research project. Nesting territories were selected for their availability and accessibility. Two territories were rejected because of the logistical difficulty of frequently accessing the site for subsequent monitoring of fledglings. Other territories were rejected because of nest failure, difficulty reaching all nestlings, or because the nestlings were very old and likely to fledge prematurely if we approached the nest ledge.

Field Protocol

Seventy-nine nestlings from 20 territories were equipped with radio transmitters. This total includes a 23-day old, prematurely fledged nestling from Beercase Downstream. This nestling was excluded from the study because it had prematurely fledged.

Therefore, only 78 nestlings from 19 territories (10 within the OTA shadow and 9 west of the OTA shadow) were included in the study (Table 1). We attempted to retrieve all members of a brood from the aerie, but 1 nestling from Fang Downstream and 1 nestling from Swan I Draw West could not be reached. A nestling from the Tom Draw territory jumped to its death as a result of investigator disturbance. Each nestling received a 6-g radio transmitter (constructed by Advanced Telemetry Systems) designed to transmit for 80 days. We attached the transmitter to the tarsus (alternating left or right) using a leather bracelet that had been cut and sewn prior to attachment so that it could be shed after the thread rotted. Transmitter weight represented less than 1% of body weight for females and just over 1% of body weight for males. Near the end of our tagging efforts, we coated several of the transmitters' antennae with yellow or blue plastic to facilitate identifying individuals from a distance.

We rappelled to each aerie when nestlings were 80% of fledging age (approximately 30 days after hatching). Brood size was determined at this time and each nestling was aged, weighed and measured (see Marzluff et al. this volume for methods). Nestlings were banded with a U.S.F.W.S. band on the right leg and a black anodized alpha-numeric band on the left leg. Nestling sex was determined by footpad length; nestlings with footpad length < 86 mm were considered males and those with larger footpads were considered to be females (Marzluff et al. 1991).

We checked territories approximately every 3 days to determine the instrumented

Table 1. Number of prairie falcon nestlings equipped with radio transmitters from each territory.

Territory	Brood size	No. nestlings equipped with radio transmitters
<u>West of OTA</u>		
Halverson Spring	2	2
Slice Draw	5	5
West Point	4	4
Cattleguard Upstream	5	5
Hell Hole Gate	1	1
Fang Downstream	6	5
Priest Rapids II	5	5
Dedication Point	4	4
Falcon Flats Engine	<u>4</u>	<u>4</u>
Total	36	35
<u>OTA Shadow</u>		
Tick III	4	4
Swan I Draw	4	4
Swan I Draw Mouth	4	4
Swan I Draw West	5	4
Slide II	5	5
Tom Draw	5	4
Massacre Face	5	5
Black Butte Ferrug	4	4
Beercase Draw	4	4
Thirst Draw DS	<u>5</u>	<u>5</u>
Total	45	43

fledglings' status until they dispersed from their natal area. A bird was considered successfully dispersed if it was not detected in or near its natal territory on 2 subsequent checks each 3 days apart. If we could not

get a visual conformation on an individual's location, we assumed that a change in signal location indicated that the fledgling was alive or we marked the signal area at the top or base of the cliff and rechecked it on the

next visit. Dead fledglings were assigned to 1 of 3 mortality causes: 1) ectoparasite infestation, 2) avian predation, and 3) unknown. Assignment was based on evidence found at the recovery site and/or from other pertinent information (Table 2).

Information on parental behavior was collected at 11 of the 19 territories (5 in the OTA shadow and 6 west of the OTA) during the late brood-rearing period (nestling age 21-40 days). We used parental attendance (% of time adults spent in the territory) and prey delivery rates (prey items delivered to the nest per hr) as measures of parental

behavior. Protocol and data collection methods for behavioral observations can be found in Marzluff et al. (this volume).

When fledglings were no longer detected in their natal areas, we scanned for the missing birds' frequencies while checking other territories and also from various locations in the study area. We obtained locations for fledglings beyond their natal territories by taking a single compass bearing toward the detected signal. Additional fledgling locations were obtained incidentally by ground-based triangulation and aerial radio-tracking crews from Greenfalk Consultants (Marzluff et al., this volume).

Table 2. Assignment of mortality causes for dead fledgling prairie falcons.

Cause	Defining Characteristic
Avian Predation	-transmitter found in raptor aerie -transmitter found in raptor pellet -fresh decapitated carcass found near owl family -owl feathers found at carcass site
Ectoparasite Infestation	-fledglings found dead in or below aeries heavily infested with ectoparasites
Unknown	-carcass scavenged or decomposed; only transmitter and body parts or feathers remained

Analyses

Standard parametric and nonparametric tests were used to investigate factors that potentially influence mortality. We used t-tests when variances were homogeneous and Mann-Whitney U tests when this assumption was not met. Pearson correlation analyses were used to test for effects of parental attendance and prey delivery rates on fledgling mortality. All percentages were transformed (arcsine of the square root) prior to analysis.

RESULTS AND DISCUSSION

Magnitude and Causes of Post-fledgling Mortality

Of the 78 instrumented nestlings, 72% ($n = 56$) survived to disperse from their natal

territories, and 28% ($n = 22$) died before dispersal (Fig. 1). This is within Sitter's (1983) determination of a 15-37% post-fledgling mortality and slightly higher than the 12-22% mortality estimated by Kochert et al. (1976) in the SRBOPA. Great-horned owls and golden eagles were responsible for 8 fledgling deaths, whereas ectoparasite infestations were implicated in 4 deaths. Causes of 10 fledgling deaths could not be determined because the carcasses were scavenged or decomposed.

Ten of the mortalities were of fledglings from nests west of the OTA shadow, and 12 were from nests within the OTA shadow. Mortalities west of the OTA shadow were predominantly caused by avian predation (6 deaths); the causes of the other 4 deaths could not be determined. Within the OTA shadow, 2 deaths were caused by avian

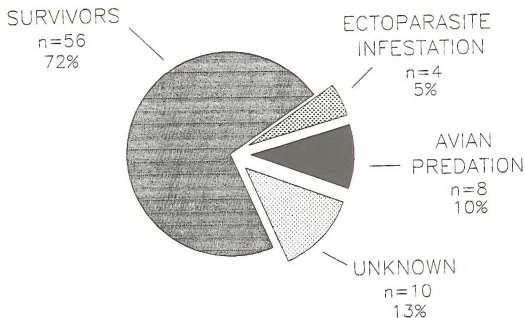


Fig. 1. Magnitude and causes of mortality for 78 prairie falcons during the post-fledgling period.

predation, 4 deaths were caused by ectoparasite infestation, and the causes of 6 deaths could not be determined.

Heavy ectoparasite infestations were observed in 2 aeries during banding. These aeries produced a total of 8 nestlings which had relatively low weights and appeared weak. On subsequent checks 2 of the 8 nestlings were found dead in these nests. We believe the remaining 6 nestlings fledged prematurely because of the irritation caused by the ectoparasites. A great-horned owl preyed upon 1 of these nestlings, and we assume 2 others died from impact (the bodies were located directly below the nest). The other 3 nestlings survived the impact of jumping and successfully dispersed.

The ectoparasites were identified as *Haematosiphon inodorus*, (family Cimicidae; A. Roe and W. Hanson, Utah State Univ.,

pers. commun.). Sitter (1983) reported that *Oeciatus vocarius* (same family) infested prairie falcon aeries in 1976. According to Usinger (1966), swallows are the native hosts to *O. vocarius* whereas birds of prey are the native hosts to *H. inodorus*. Platt (1975) attributed the abandonment of 1 clutch of eggs and 7 nestling deaths to the presence of *H. inodorus* in prairie falcon nests. We could not find any literature that documented raptors as hosts to *O. vocarius*.

Timing of Mortality

During the first week after the nestlings were equipped with radio transmitters the number of survivors declined by 14% (Fig. 2). This decline represents half of all mortality and includes only young ($n = 11$) that died before reaching the usual fledging age of 38 days. Therefore, assessments of fledging success made when nestlings were

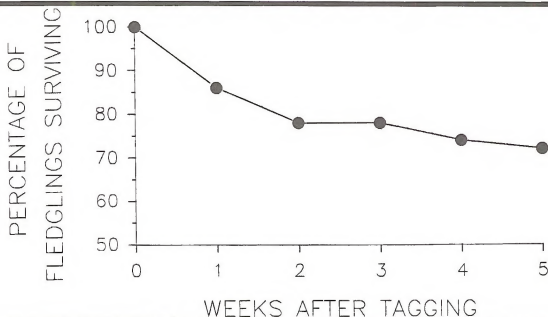


Fig. 2. Percentage of fledglings surviving from day 0 (day equipped with radio transmitter) through the post-fledging period until dispersal from the natal territory occurred during week 5.

80% of fledging age did not accurately represent actual fledging success. The number of survivors declined an additional 9% during the second week. The average age of fledglings that died was 40.9 days which corresponds with the second week post-tagging. Over the next 3 weeks, survivors decreased by 5 percent. By the fifth week, 72% of the fledglings survived to disperse. Mean dispersal age was 64.6 days (range = 50.5-75.0 days) for males and 66.8 days (range = 59.5-78.5 days) for females.

Fledglings dying from causes associated with ectoparasite infestations were significantly younger (mean age = 32.4 days, SD = 0.75, $n = 4$) than those dying from avian predation (mean age = 43.3 days, SD = 10.2, $n = 8$), ($U = 32.0$, $P = 0.006$; Fig. 3). The young age of death for mortalities influenced by parasite infestations was expected because nestlings from infested aeries had relatively low weights and appeared to be weak. They were unlikely to be able to evade predators once they left the security of their nests.

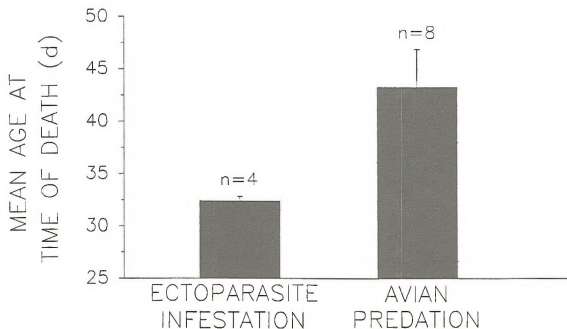


Fig. 3. Mean age (+ 1 SE) at the time of fledgling death in relation to mortality causes.

Factors That May Influence Post-fledging Mortality

Nestling weight.--A nestling's weight may be a general indicator of its condition and therefore might correlate with its subsequent survival (Lack 1954). However, this is not always the case (Newton 1986). We found no relationship between nestling weight and subsequent survival during the post-

fledging period. There was no significant difference in weight at tagging between males that survived (mean = 545.4 g, SD = 39.3, $n = 27$) and those that died (mean = 537.3 g, SD = 60.0, $n = 11$; $t = 0.49$, $P = 0.63$). Likewise, females that survived (mean = 799.8 g, SD = 66.9, $n = 29$) were similar in weight at tagging to those that died (mean = 763.2 g, SD = 101.2, $n = 11$; $t = 1.34$, $P = 0.19$; Fig. 4).



Fig. 4. Mean nestling weight (+ 1 SE) and the relationship between male and female fledglings that survived and died.

It appears that the 2 major sources of mortality selected against fledglings of different weights. The mean weights at tagging of males and of females that died from parasite infestations were much lower than those of individuals that died from avian predation (Fig. 5). Due to small sample size for females in the ectoparasite infestation category we only tested the influence of weight on the source of mortality for males. Males that died from parasite infestations (mean weight at tagging

= 455.0 g, SD = 37.7, $n = 3$) had significantly lower weights than those that died from predation (mean weight at tagging = 552.5 g, SD = 15.5, $n = 4$; $U = 12.00$, $P = 0.03$). Because avian predation and the unknown cause category were the primary mortality sources in this study, nestling weight was not a good indicator of subsequent survival. Fledglings that died from predation or from unknown causes also had similar weights at tagging to those that survived (Fig. 5).

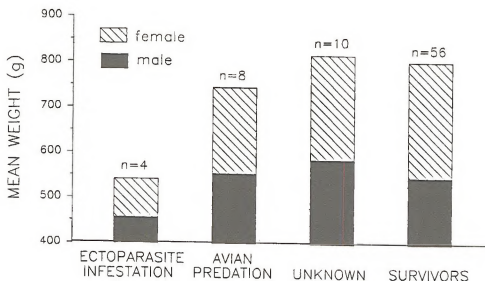


Fig. 5. Mean nestling weight for male and female fledglings that died and the causes of their mortality. The survivor category shows relative similarities in weights to fledglings that died from avian predation and unknown causes.

Nestling weights of males that died (mean = 525.0 g, SD = 81.6, $n = 6$) from OTA shadow nests did not differ significantly from nestling weights of males that died (mean = 552.0 g, SD = 13.05, $n = 5$) from nests west of OTA ($t = 0.73$, $P = 0.49$). Nestling weights of females that died also did not differ significantly with respect to proximity to the OTA (OTA shadow: mean = 740.8 g, SD = 131.1, $n = 6$; west of OTA: mean = 790.0 g, SD = 48.6, $n = 5$; $t = 0.79$, $P = 0.45$).

Parental behavior.--Parental behavior during the late brood-rearing period did not correlate with post-fledging mortality. We found no relationship between the amount of time an adult spent in the territory and brood mortality (males: $r = -0.14$, $P = 0.69$, $n = 11$ broods; females: $r = -0.04$, $P = 0.89$, $n = 11$ broods; Fig. 6). Prey delivery rates (male and female total) also were not correlated with brood mortality ($r = -0.013$, $P = 0.97$,

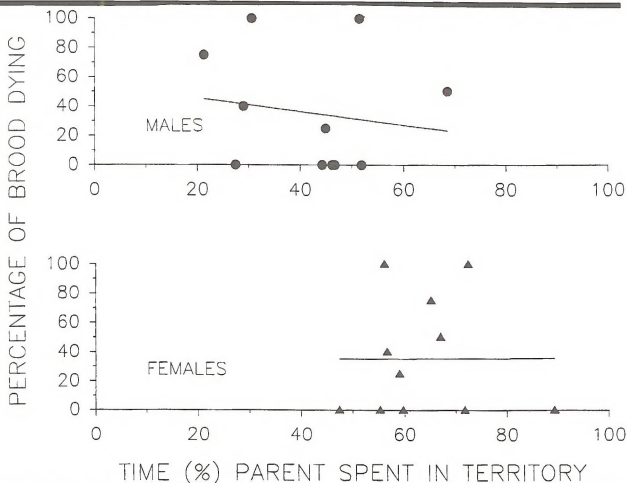


Fig. 6. Pearson correlations between male and female parental attendance during the late brood rearing period (nestling age 21-40 days) and the percentage of their broods dying post-fledging.

$n = 11$ broods, Fig. 7). This result is as expected because we did not see any difference in nestling weight between fledglings that survived and those that died.

Hatch date.--Parents who breed early in the season may have a reproductive advantage over those who breed later on. Early breeders may be socially or genetically

superior to later breeders and/or reap the benefits of occupying higher quality nesting and foraging areas. This may enable early breeders to produce nestlings with greater post-fledging survivorship than late breeders (Newton 1986). We found a significant advantage ($t = 2.22$, $df = 29.3$, $P = 0.03$) to breeding early; fledglings that died ($n = 22$), had later average hatch dates than those that

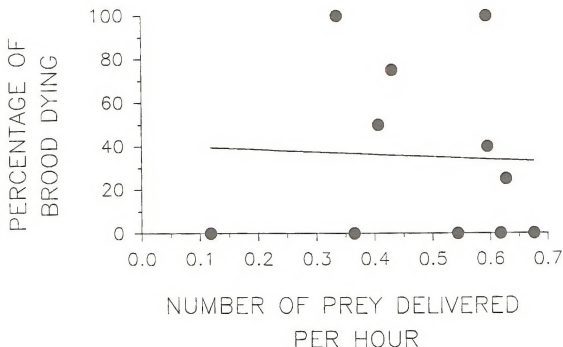


Fig. 7. Pearson correlation between prey delivery rates made by both parents during the late brood rearing period (nestling age 21-40 days) and the percentage of their broods dying post-fledging.

survived ($n = 56$) (Fig. 8). Hatch dates (mean Julian date = 111.9, SD = 6.5) for broods of 5 nestlings ($n = 8$) were significantly earlier than hatch dates (mean Julian date = 127.0, SD = 12.7) for broods of 4 nestlings ($n = 8$) ($t = 2.3$, $P = 0.010$). Early hatching broods produced more young per brood than late hatching broods. Korpimäki and Lagerstrom (1988) found that early clutches of Tengmalm's owls (*Aegolius funereus*) produced more young than late clutches. Prairie falcon hatch dates spanned

a range of 6 weeks in 1992 (early April to late May). A partial explanation for the influence of hatch date on post-fledging mortality may be that parasites infested aeries of late nesting parents more frequently than early nesting parents. Also, many Townsend's ground squirrels (*Spermophilus townsendii*) estivate in June (Smith and Johnson 1985), possibly making it more difficult for late nesting parents to secure adequate prey for their fledglings.

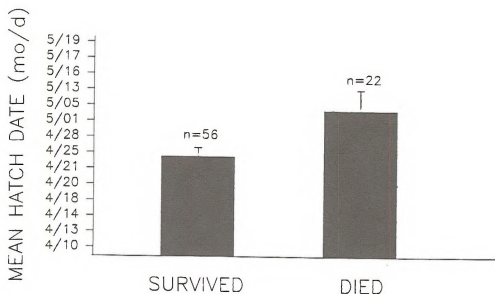


Fig. 8. Mean hatch date (+ 1 SE) of fledglings that survived and those that died.

Brood size.--We were interested in determining if brood size at 80% of fledging age influenced the number of individuals that died within a brood; nests fledging large broods should produce more survivors than those fledging small broods. Newton (1986) concluded that subsequent survival of

sparrowhawks was not related to brood size at fledging. We also found no relationship between brood size at fledging and survival rate during the post-fledging period ($t = 0.26$, $P = 0.79$, $n = 16$ broods; Fig. 9). Brood size was significantly correlated with the number of fledglings dispersing from a

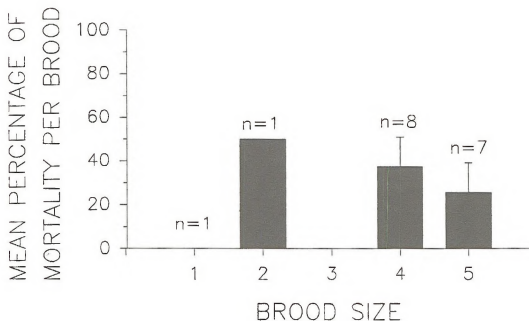


Fig. 9. Mean percentage (+ 1 SE) of mortality per brood compared with brood size at banding time.

territory ($r = 0.74$, $P < 0.001$, $n = 25$; Fig. 10). However, there was considerable scatter in this relationship and caution should be applied in interpretations of brood size as a measure of productivity. Brood sizes of 4 and 5 produced significantly more dispersers

than did broods of 0, 1, or 2. But there was not a significant difference in post-fledging productivity between broods producing 4 versus those producing 5 or between those producing 1 versus those producing 2 fledglings.

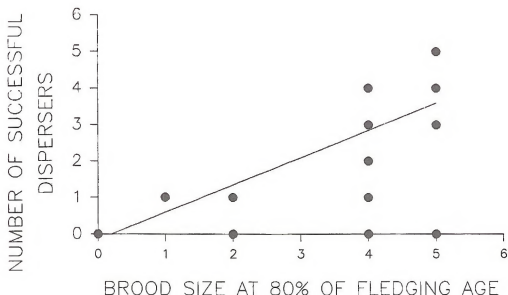


Fig. 10. Pearson correlation between the number of fledglings that successfully dispersed from the natal territory and brood size when nestlings were 80% of fledgling age.

Fledgling Locations Beyond the Natal Territory

Fledgling locations beyond the natal territory were recorded for 39 individuals from 16 broods (Fig. 11). The majority of locations

were single compass bearings taken toward detected signals and only represent a crude pattern of space use by fledglings. However, it is apparent that the area between Initial Point and the northwest corner the range road was highly utilized by fledglings.

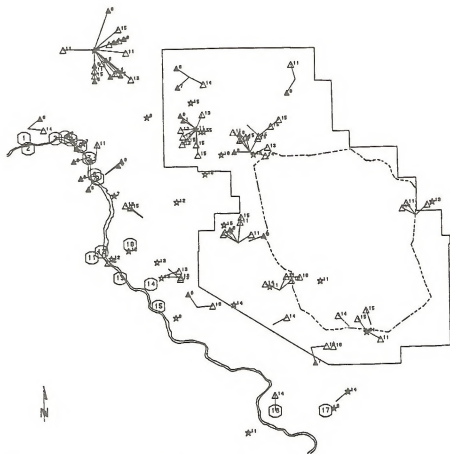


Fig. 11. Locations of fledglings beyond their natal territories. Filled symbols indicate locations for fledglings hatched west of the OTA and open symbols indicate locations for fledglings hatched inside the OTA shadow. Stars indicate point estimates obtained by visual observations, triangulation, or aerial tracking. Triangles are locations from which bearings were taken toward fledglings. Direction of the fledglings' signals from the triangle is indicated by the line out of the symbol.

■ PLANS FOR 1993

In 1993, we plan to continue with the same objectives as those for 1992. We will equip approximately 80 nestlings with radio transmitters and monitor their survival.

■ ACKNOWLEDGMENTS

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Appendix A: Leg band combinations, radio frequencies, and mortality causes of prairie falcon fledglings that died during the post-fledging period.

Territory	Frequency	Leg Bands		Mortality Cause*
		Alpha-Numeric	USFWS	
<u>West of OTA</u>				
CATTLEGUARD UPSTREAM	165.334	6/G	816-74880	predation
CATTLEGUARD UPSTREAM	165.444	K/S	1807-38693	unknown
HALVERSON SPRING	165.294	5/3	1807-38672	predation
SLICE DRAW	165.425	A/V	1807-38680	predation
SLICE DRAW	165.772	B/A	1807-38670	predation
SLICE DRAW	165.353	4/D	816-74862	unknown
SLICE DRAW	165.602	4/E	816-74863	predation
SLICE DRAW	165.253	5/0	816-74864	predation
WEST POINT	165.474	L/3	1807-38699	unknown
WEST POINT	165.004	L/5	1807-38537	unknown
<u>OTA Shadow</u>				
BEERCASE				
DOWNSTREAM	165.613	-	816-74877	predation
BEERCASE DRAW	165.763	3/N	816-74898	unknown
BEERCASE DRAW	165.144	3/M	816-74897	unknown
BEERCASE DRAW	165.393	L/6	1807-38538	predation
BEERCASE DRAW	165.654	L/7	1807-38539	unknown
BLACK BUTTE FERRUG	165.194	C/P	1807-38657	unknown
MASSACRE FACE	165.693	4/8	816-74866	unknown
SLIDE II	165.243	A/K	1807-38678	unknown
SWAN I DRAW	165.484	3/H	816-74836	ectoparasites
SWAN I DRAW	165.013	-	1807-41408	predation
SWAN I DRAW MOUTH	165.654	6/S	816-74891	ectoparasites
SWAN I DRAW MOUTH	165.684	6/T	816-74892	ectoparasites
SWAN I DRAW MOUTH	165.563	4/1	1807-38697	ectoparasites

*Mortality causes:

predation=death was caused by a golden eagle or a great-horned owl
 ectoparasites=death was directly or indirectly caused by ectoparasites
 unknown=cause of death could not be determined

Red-Tailed Hawk Predation on Snakes: The Effects of Weather and Snake Activity

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ANNUAL SUMMARY

A thesis was completed in 1992, in partial fulfillment of the requirements for a Master's Degree at Idaho State University. An abstract of the thesis is presented here.

■ OBJECTIVES

1. Examine how weather conditions and snake activity affect red-tailed hawk predation on snakes.
2. Examine how species of prey and the times of delivery to the nest vary throughout the day and nesting season.

totaling 537.6 hrs. Body temperature and activity of 11 gopher snakes (*Pituophis catenifer*) implanted with activity and temperature-sensitive radio transmitters were recorded with automated telemetry equipment for 6,051 snake hrs. Weather stations collected meteorological data and snake model temperatures for analysis of the effects of weather on snake activity and red-tailed hawk predation.

■ RESULTS

The dynamics of weather and snake activity on red-tailed hawk (*Buteo jamaicensis*) predation on snakes were measured by recording the number, type, and times of prey delivered to hawk nests during 1990 and 1991 nesting periods on the Snake River Birds of Prey Area in southwestern Idaho. These data were determined through direct observation of prey deliveries to 2 nests in 1990 and 1 in 1991,

Gopher snakes emerged 63% (102 of 170) of the days monitored. Gopher snake activity was correlated with environmental temperature ($r^2 = 0.554$, $P < 0.001$, $n = 68$). Gopher snakes, racers (*Coluber constrictor*), striped whipsnakes (*Masticophis taeniatus*), and unidentified snakes made up 48.6% (104 of 214) of the observed red-tailed hawk prey items. These snakes made up an estimated 66.3% of the total observed diet biomass. There appeared to be a decrease in red-tailed hawk hunting activity between 1200 and 1400

hrs, which is the same time that both male and female gopher snake activity is at its peak. There was a significantly greater proportion of snakes delivered to the nests when model temperatures were between 30 C and 40 C ($G = 31.13$, $P < 0.05$, $n = 95$), whereas, small

mammals were consistently captured over all model temperatures. These results show that snakes were most likely to be preyed upon in the late morning and late afternoon when environmental temperatures were moderately high and when gopher snakes were active.



Use of Nest Boxes by American Kestrels in Southwestern Idaho

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ANNUAL SUMMARY

*American kestrels (*Falco sparverius*) nested in 23 boxes along I-84 and in the vicinity of Kuna, Idaho in 1992. Occupancy rates (46%) were the same as in 1991, and nesting success rates (70%) were higher than the long-term average. Eighty-eight kestrels were banded along the 2 routes in 1992.*

■ OBJECTIVES:

1. Determine kestrel occupancy rates and nesting success at boxes erected in southwestern Idaho.
2. Mark nestling and adult kestrels to accumulate baseline data for future studies on dispersal and population dynamics.

The limited use of those boxes prompted curiosity about factors that influence occupancy rates. In 1986, the Idaho Fish and Game Department's Nongame program joined the study, and the study area expanded to include agricultural and suburban habitat in the Kuna area as well as Interstate 84 between Simco Road and Caldwell. From 1989 to 1992, BLM had sole responsibility for monitoring the boxes.

■ INTRODUCTION

This study began in 1985 when nest boxes were erected on abandoned power poles in the Snake River Birds of Prey Area in an effort to learn more about the food habits and breeding biology of American kestrels in southwestern Idaho (Steenhof et al. 1985).

■ METHODS

Boxes have been erected for kestrels in 3 separate study areas in southwestern Idaho: on trees within agricultural habitat in the vicinity of Kuna, Idaho (hereafter referred to as the Kuna Route); on highway signs along Interstate 84 between Simco Road and

Caldwell (hereafter referred to as the I-84 route); and on abandoned power poles along the north rim of the Snake River Canyon (hereafter referred to as the BOPA route). Monitoring in 1991 focused on the boxes on the Kuna and I-84 routes because of high vandalism and low kestrel occupancy rates on the BOPA route (Steenhof 1989). In 1992, 28 boxes were available on the I-84 route, and 22 were available on the Kuna route. Several boxes on both routes have been destroyed since the study began.

Most boxes were checked in early April, and we repaired boxes and added shavings at that time. All boxes on the Kuna route and I-84 route were checked again in May, and boxes with viable nesting attempts were re-visited from late May through July as necessary to band young and ascertain nesting success.

Nests with young that could be sexed (75% feathered) were considered successful. Investigators checked boxes while standing on a ladder. When checking boxes, investigators inserted a hole stuffer into the nest box entrance to trap any adult birds in the box. Adults and young were weighed with a 300-g Pesola balance. Nests of European starlings (*Sturnus vulgaris*) were removed in an effort to keep all boxes suitable for kestrel nesting.

RESULTS

Twenty-three (46%) of 50 available boxes on the Kuna and I-84 routes were used for nesting by kestrels in 1992. The 1992 box occupancy rate was the same as in 1991 and higher than occupancy rates on these 2 routes in previous years (Table 1).

Table 1. Occupancy rates of kestrel boxes on the Kuna and I-84 routes, 1986-1991. Number of available boxes in parentheses.

Year	I-84	Kuna	Overall
1986	24% (17)	18% (17)	21% (34)
1987	41% (32)	39% (31)	40% (63)
1988	30% (30)	40% (30)	35% (60)
1989	28% (29)	27% (30)	27% (59)
1990	36% (28)	38% (26)	37% (54)
1991	36% (28)	58% (24)	46% (52)
1992	36% (28)	59% (22)	46% (50)
\bar{x}	33%	40%	36%

Occupancy rates on the I-84 and Kuna route (59%) were higher than occupancy rates of I-84 boxes (36%) in 1992, but differences were not significant. The number of boxes occupied by kestrels on the Kuna route decreased from 14 in 1991 to 13 in 1992, whereas the number of occupied I-84 boxes remained at 10 for the third consecutive year. Although the number of boxes used on I-84 has been steady, different boxes have been used each year; only half of the boxes used in 1992 were used in 1991. Three others had been used in 1990, and 2 had not been used since 1987.

Three boxes were used by kestrels for the first time on the Kuna route in 1992. Most

of the occupied Kuna boxes (7) had been used in 1991; 2 were last used in 1989, and 1 was last used in 1988.

Overall nesting success of 23 kestrel pairs in 1992 was 70%, above the 7-year average of 61% (Table 2). Sixty percent of I-84 nests were successful, and 77% of nests on the Kuna route were successful. One kestrel pair re-nested in an I-84 nest box, but both attempts failed. Three of 16 successful nests had at least 1 egg that failed to hatch, and nestlings died at an additional site. Observed clutch sizes ranged from 4 to 6 in 1992; clutch size was 5 in 18 of 20 cases. We observed a brood of 6 for the fourth consecutive year.

Table 2. Percent of kestrel nests successful on the Kuna and I-84 routes, 1986-1992. Sample sizes in parentheses.

Year	I-84	Kuna	Overall
1986	0% (3)	100% (4)	57% (7)
1987	54% (13)	55% (11)	54% (24)
1988	44% (9)	50% (12)	48% (21)
1989	25% (8)	75% (8)	50% (16)
1990	80% (10)	89% (9)	84% (19)
1991	70% (10)	64% (14)	67% (24)
1992	60% (10)	77% (13)	70% (23)
\bar{x}	48%	73%	61%

We banded 88 kestrels along the 2 routes in 1992 (73 nestlings and 15 adults). (George Carpenter banded 150 more kestrels in his new boxes). In 1992, Carpenter captured 2 females previously banded in Kuna nest box #3. One had been banded in 1990 as a breeding adult; in 1992 she nested unsuccessfully in 1 of Carpenter's boxes, less than 0.5 km from her 1990 nesting box. The second female captured by Carpenter was an offspring of the first recaptured female. She had been banded as a nestling in 1990, and Carpenter captured her as a successfully breeding adult 8.4 km from her natal box.

A third banded female kestrel was found dead by a private citizen during the 1992 breeding season, 3.1 km from Kuna box #7 where she nested in 1991. She also may have been associated with 1 of Carpenter's nest boxes. We also received a report of a male kestrel banded as a nestling in 1991 at an I-84 box. The male was found dead somewhere in Boise in April 1992, but no additional details were available.

Starlings nested in 26 of the 50 boxes in 1991, and house sparrows (*Passer domesticus*) nested in 2 boxes. Only 1 box had no confirmed use by any species during the nesting season. All house sparrow nests were on the Kuna route. Starling occupancy

rates were highest along the I-84 route, where 19 of 28 boxes (68%) were used by starlings. On the Kuna route, starlings nested in only 7 boxes (32%). Kestrels took over 1 of the Kuna boxes used by starlings, and starlings nested in an I-84 box after kestrel eggs were abandoned. Weights of adult females ranged from 126 to 160 g and averaged 140 g ($n = 14$; $SD = 9.7$). One adult male weight 107 g.

■ PLANS FOR NEXT YEAR

Monitoring in 1993 will continue, in cooperation with George Carpenter's graduate study on kestrel sex ratios. We will attempt to trap and band all breeding adults in 1993.

■ ACKNOWLEDGMENTS

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Offspring Sex Ratios of American Kestrels in Southwestern Idaho

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ANNUAL SUMMARY

*I initiated a 2-year study of offspring sex ratios in American kestrels (*Falco sparverius*) near Kuna, Idaho. Fisher's and Myers' hypotheses were tested, and sex biases in laying and hatching sequences were explored. Preliminary results were mostly inconclusive due to low sample sizes, but the data did not support Fisher's hypothesis.*

■ OBJECTIVES

1. Test Fisher's (1930) hypothesis.
2. Test Myers' (1978) hypothesis.
3. Determine if kestrels show sexual biases with laying or hatching sequences.

■ INTRODUCTION

Can breeding birds adjust the sex ratios of broods they produce? Some studies have reported ratios deviating from unity, but whether or not gender manipulation is a significant and widespread practice is

unclear (reviewed by Clutton-brock 1986). Assuming that birds can control offspring sex, hypotheses have been offered that predict when and how sex ratio may be manipulated.

Fisher (1930) suggested that breeders may maximize fitness by investing equally in offspring of each sex. In size dimorphic species, 1 sex may be energetically less expensive to rear than the other, so a lifetime production bias toward the cheaper sex would be predicted (Howe 1977). Dimorphic birds produced ratios biased toward the smaller, cheaper sex in agreement with Fisher's hypothesis in some studies (Howe 1977, Ligon and Ligon 1990, Bednarz and Hayden 1991). Others showed

avian sex ratios that approached unity (Newton and Marquiss 1979, Richter 1983, Weatherhead 1985, Dijkstra 1988).

Myers (1978) proposed that individuals may skew sex ratios toward the more expensive sex when resources are abundant and toward the cheaper sex when resources are in short supply. Myers' hypothesis was supported in some avian studies (Howe 1977, Patterson et al. 1980, Ligon and Ligon 1990, Wiebe and Bortolotti 1992) and rejected in others (Dijkstra 1988, Bednarz and Hayden 1991).

Birds may use sex-biased hatching sequences to adjust secondary offspring sex ratios (Fiala 1981, Ryder 1983, Weatherhead 1985, Bortolotti 1986, Bednarz and Hayden 1991, Wiebe and Bortolotti 1992). Such sequence biases may affect brood sex ratios directly, or indirectly by influencing competitive interactions among brood mates (Bednarz and Hayden 1991).

In 1992, I began a 2-year study of sex ratios in American kestrels (*Falco sparverius*) near Kuna, Idaho in and adjacent to the Snake River Bird of Prey Area. I addressed 3 major questions: 1) Is there a gender bias in offspring produced as predicted by Fisher's hypothesis; 2) is the offspring sex ratio altered when food is more available in support of Myers' hypothesis; and 3) is there a sexual bias with laying or hatching sequence?

■ METHODS

Bureau of Land Management (BLM) staff, several volunteers, and I monitored kestrel breeding activity in 126 nest boxes in 2 adjacent study areas. Fifty boxes were in Study Area A (those in the Kuna and I-84

Routes as described by Steenhof, this volume), and 76 boxes were in Study Area B. Most Area A boxes have been present since 1986 (Steenhof, this volume), but Area B boxes were erected in February 1992.

Several assistants and I monitored Study Area B boxes. Beginning 1 March, kestrel activity near these sites was observed to identify occupancy (status follows Steenhof 1987). We inspected occupied boxes 4 to 7 times a week to identify laying and hatching sequences. Kestrel eggs and hatchlings were individually marked with felt pen ink. Nestling identities were maintained by remarking 3 times a week until the chicks were banded at about 12 days of age. Nestlings were weighed and measured 3 times a week, and boxes that contained chicks at least 22 days old were inspected daily to determine approximate fledging dates.

BLM staff visited boxes in Study Area A. They inspected each box at least twice during the breeding season to record occupancy, sex ratios near fledging age, and other data (Steenhof, this volume).

I tested Myers' hypothesis 3 ways. First, I compared sex ratios of randomly selected pairs offered house mice and young Japanese quail to ratios of unsupplemented controls. Food was offered 3 to 4 times a week from site occupancy to desertion or fledging in 30-cm sections of 8-cm² vinyl tubing mounted approximately 30 cm below nest boxes parallel to ground level. Second, I considered the effect of irrigation on sex ratio because irrigated land may have supported more prey than dry land. Nest boxes within 800 m of irrigated areas were compared with boxes greater than 800 m from irrigation. Finally, I compared offspring

sex ratios produced by early and late nesting pairs. Those with young that hatched prior to the median hatching date may have had greater food resources than those with later hatched young.

• PRELIMINARY RESULTS AND DISCUSSION

Box use and banding

Nest box use and banding data for Study Area A were reported in Steenhof (this volume). In Study Area B, 37 (49%) of 76 available boxes were occupied at least once in 1992. Three occupied boxes were deserted and reoccupied. Occupancy rate in Area B was similar to the 46% observed in Area A in 1992, even though Area B boxes were erected in February 1992, and Area A boxes had been available since 1986 (Steenhof, this volume).

Twenty-six (76%) of 34 breeding attempts were successful in Study Area B in 1992. Kestrels abandoned 6 boxes within 2 days of egg laying, 1 incubated clutch did not hatch, and 1 box was deserted with 4 to 7 day old chicks. Two chicks died in 1 box, and single chicks died in 3 boxes. Nesting success was similar to the 70% observed in Study Area A (Steenhof, this volume). The similarity indicates that frequent nest visits in Area B may not have influenced nesting success.

We banded 150 kestrels in Area B in 1992. Four of these birds were adult males, 16 were adult females, 63 were nestling males, and 67 were nestling females.

Sex ratios and Fisher's hypothesis

Fisher's (1930) hypothesis predicted sex ratios biased toward the cheaper sex. I assumed that if fledglings of 1 gender were smaller and/or left the nest sooner than fledglings of the other sex, the former would be less expensive to produce (Fiala and Congdon 1983, Richter 1983).

Males and females fledged at about 28 days of age (Table 1), but males weighed about 7% less than females (Table 2). Fledgling mass disparities were similar to those found in wild kestrels in Saskatchewan (Wiebe and Bortolotti 1992) and captive kestrels in Quebec (Bird and Clark 1983). Though both sexes fledged at the same age, males were smaller and therefore probably cheaper.

Most appropriately, Fisher's hypothesis would be tested with lifetime production data for individual breeders. I sampled sex ratios from a population of breeders and assumed the mean reflected output of an average individual. Both primary and secondary ratios were calculated (Table 3). Primary sex ratio refers to the proportion of males at conception (Fiala 1980). I approximated mean primary sex ratio using ratios for broods that had no egg or chick losses prior to about 15 days after the last chick hatched (Wiebe and Bortolotti 1992, but see Fiala 1980), a time when sexes may be determined by plumage (Parkes 1955). Secondary sex ratio is the ratio at termination of parental care (Fisher 1930), and I approximated it as the ratio when brood mates averaged 22 days of age (Richter 1983, but see Slagsvold et al. 1986). Though I had an inadequate sample size for

Table 1. Age at fledging of American kestrels in Southwestern Idaho, 1992.

	First chick, by brood ^a			All chicks, by brood ^b			All chicks, pooled		
	Days	SE	<i>n</i>	Days	SE	<i>n</i>	Days	SE	<i>n</i>
Male	28.3	0.7	11	27.9	0.4	20	28.1	0.3	46
Female	28.0	0.7	13	27.8	0.6	21	27.6	0.3	53
<i>P</i> ^c	0.59			0.44			0.40		

^a First hatched chick in each brood.

^b Median age of male/female chicks in each brood.

^c t-test

Table 2. Mass at fledging of American kestrels in Southwestern Idaho, 1992.

	First chick, by brood ^a			All chicks, by brood ^b			All chicks, pooled		
	g	SE	<i>n</i>	g	SE	<i>n</i>	g	SE	<i>n</i>
Male	105.0	3.5	10	108.0	2.1	20	108.8	1.5	46
Female	119.3	2.9	14	116.1	3.3	21	116.0	2.2	53
<i>P</i>	0.88 ^c			0.01 ^d			0.00 ^c		

^a First hatched chick in each brood.

^b Median age of male/female chicks in each brood.

^c t-test

^d Wilcoxon test

Table 3. Offspring sex ratios of American kestrels in Southwestern Idaho, 1992.

	<u>Proportion males</u>	<u>Number males/females</u>	<u>P^a</u>
Primary ^b	0.48	30/32	1.00
Secondary ^c	0.46	92/108	0.48

^a G-test

^b Ratio for broods with no egg or chick losses when youngest chicks were 15 days old.

^c Ratio for broods that fledged at least 1 chick when the mean age of brood mates was 22 days.

primary sex ratio ($n = 62$), secondary sex ratios did not differ from unity.

Preliminary results indicated that secondary sex ratios were not biased toward the cheaper sex as predicted by Fisher's hypothesis. My data partially agreed with Wiebe and Bortolotti's (1992) 3-season study with ratios ranging from unity to male-biased. Neither study agreed with the female-biased ratio calculated by pooling data from the literature (Olsen and Cockburn 1991, but see Wiebe and Bortolotti 1992).

Sex ratio manipulation and Myers' hypothesis

First year results suggested no effect of food supplementation, irrigation, or timing on sex ratios as predicted by Myers' hypothesis (Table 4). However, there was a slight male-bias for supplemented and irrigated sites. Due to small sample sizes for these interaction groups, I considered this preliminary result insignificant. Wiebe and Bortolotti (1992) found that sex ratio was independent of laying date classified as early or late, similar to my results.

Sex biases of laying and hatching sequences

Due to considerable hatching synchrony, laying and hatching sequences often went undetected. With resulting low sample sizes, none of the male proportions differed significantly from 0.5 for all laying and hatching sequences. Interestingly, 6 of 12 first hatched chicks were male.

PLANS FOR NEXT YEAR

Plans for the second and final season of the study have not been completed. Most likely, approaches and techniques will not change from those in the 1992 season, but priorities may be shifted to improve sample sizes for some comparisons.

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Table 4. Analysis of variance results for the effect of food availability on secondary sex ratio^a in American kestrels in Southwestern Idaho, 1992.

Food availability variable(s)	R^2	P^b
Feeding treatment ^c	0.08	0.19
Irrigation ^d	0.00	0.85
Timing ^e	0.03	0.20
Feeding treatment * irrigation	0.20	0.04
Feeding treatment * timing	0.00	0.87
Irrigation * timing	0.05	0.66

^a Ratio for broods that fledged at least 1 chick when the mean age of brood mates was 22 days.

^b $n = 22$

^c Food supplemented broods compared to unsupplemented controls.

^d Broods in nest boxes within 800 m of irrigated land compared to broods in boxes greater than 800 m from irrigation.

^e Broods produced early in the season compared to late broods, separated into 2 groups by mean brood hatching dates.

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Nest Box Use and Breeding Biology of Northern Saw-whet Owls in Southwestern Idaho

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ANNUAL SUMMARY

*This study focused on the breeding biology of northern saw-whet owls (*Aegolius acadicus*) using nest boxes in 3 riparian habitat types (desert/shrubland, cottonwood/agriculture, and coniferous forest). The habitat types occurred at 2 elevations that averaged 800 m and 1,550 m. Nest boxes occupied by northern saw-whet owls were checked weekly to determine reproductive success and to collect diet information. Five northern saw-whet owl breeding attempts were successful producing a total of 23 young. Thirty northern saw-whet owls were banded. Diet of the owls included *Peromyscus maniculatus*, *Mus musculus*, and *Microtus montanus*.*

■ OBJECTIVES

1. To determine nest box use and dates of peak nest box use.
2. To determine breeding biology of northern saw-whet owls.
3. To determine breeding season diet of northern saw-whet owls.
4. To locate and characterize roost sites.

5. To characterize habitat at occupied and randomly selected unoccupied nest boxes.

■ INTRODUCTION

The northern saw-whet owl (*Aegolius acadicus*) is a small owl found only in North America (Johnsgard 1988). Although considered common, little information is available on the species' status, population

trends, and breeding biology (Cannings 1987, Johnsgard 1988, Marks and Doremus 1988). This study is focusing on northern saw-whet owl breeding biology, diet, and habitat use in 3 study areas in southwestern Idaho.

STUDY AREAS

The 3 study areas of this study include 3 habitat types, desert/shrubland riparian, cottonwood/agriculture riparian, and coniferous forest riparian.

Desert/shrubland Riparian Habitat Type.-- Owl use of the desert/shrubland riparian habitat type was examined on U.S. Bureau of Land Management (BLM) land at C.J. Strike Reservoir in the Snake River Birds of Prey Area (SRBOPA) in southwestern Idaho, and within the C.J. Strike Wildlife Management Area (Fig. 1). Riparian habitats there consist of scattered groves of Russian olive (*Elaeagnus angustifolia*), black locust (*Robinia pseudoacacia*), and willow (*Salix* spp.) occupying shoreline areas and adjacent drainages. Elevation in the study area ranges from 775-800 m.

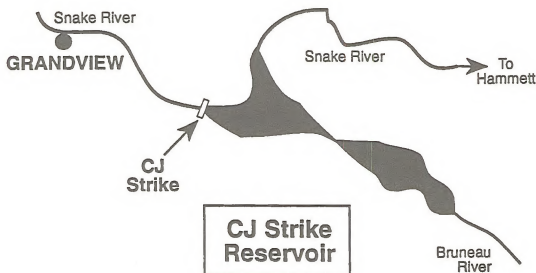


Fig. 1. Snake River Birds of Prey Area (SRBOPA) study area, southwest Idaho.

Cottonwood/Agriculture Riparian Habitat Type.--Owl use of the cottonwood/agricultural habitat type was examined at Lake Lowell in the Deer Flat National Wildlife Refuge (DFNWR), near Nampa Idaho (Fig. 2). Lake Lowell is an artificial impoundment created in the early 1900's by construction of the New York Canal. Historically a shrub steppe environment, Lake Lowell is now surrounded by stands of cottonwood (*Populus* spp.), willow, and salt cedar (*Tamarix* spp.). Elevation at Lake Lowell is 800 m.

Coniferous Forest Riparian Habitat Type.--Owl use of coniferous forest habitat was examined on U. S. Bureau of Reclamation (BOR) lands adjacent to Cascade Reservoir in westcentral Idaho (Fig. 3). Vegetation in the area consists primarily of lodgepole pine (*Pinus contorta*), ponderosa pine (*P. ponderosa*), and quaking aspen (*Populus tremuloides*). Elevation in this study area varies between 1,520-2,140 m.

• METHODS

Nest box erection and cleaning.--Five nest boxes designed to accommodate small owls, American kestrels (*Falco sparverius*), and wood ducks (*Aix sponsa*) were erected in suitable habitat within the SRBOPA. These boxes were added to the 75 nest boxes currently in place for the western screech-owl (*Otus kennicottii*) study of John Doremus (Doremus, this volume).

Fifty nest boxes designed to accommodate small owls were placed on trees in the northwest and northeast riparian areas of Cascade Reservoir on Bureau of Reclamation property. Trees were selected based on their

isolation from human disturbance and roads, and on their proximity to other trees and/or other cover types, and openings in the tree stand. Boxes were placed approximately 3 m above the ground.

Approximately 10 cm of wood shavings were placed as nesting material. Old nesting material was always removed and replaced with new nesting material if it was dirty or if it contained materials brought into the box by other species. Nesting material was added to boxes as needed throughout the study.

Nest box surveys.--From 11 February through 27 June all nest boxes were checked every 2 weeks for occupancy and to determine dates of peak nest box use for all species. A box was considered occupied if it contained adults, young, or eggs of a known species. In most cases, nest boxes were checked using a ladder. If a bird or mammal was seen on or leaving the box it was classified as occupied. Occupancy for DFNWR was calculated for 114 of the 129 boxes in place, the other 15 boxes were located adjacent to a bald eagle (*Haliaeetus leucocephalus*) nest and were not checked throughout most of the study to avoid possible disturbance. However, after the eagle nest failed the boxes were checked twice at the end of the breeding season.

Breeding Biology.--Nest boxes occupied by northern saw-whet owls were checked weekly to determine clutch size, hatching success, nesting success, and fledging success. Whenever possible the female owl was captured, banded, weighed (pesola scale), and measured (wing cord, seventh primary) to the nearest mm using a ruler. Owls caught inside the nest box were determined to be females by the presence of

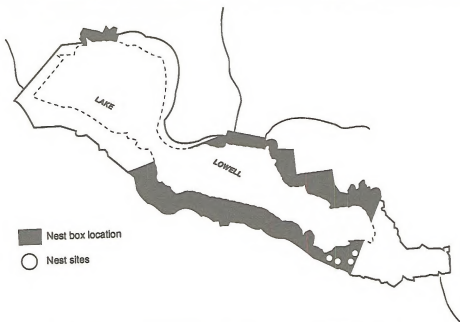


Fig. 2. Deer Flat National Wildlife Refuge (DFNWR) study area, southwest Idaho. Dark area shows area of nest box locations, small circles indicate boxes occupied by northern saw-whet owls (*Aegolius acadicus*) in 1992.

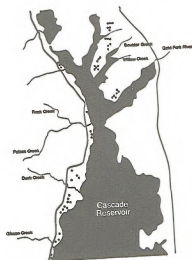


Fig. 3. Cascade Reservoir study area, westcentral Idaho. Small dots indicate location of nest boxes.

a brood patch, and their weight. When nestling saw-whet owls had reached 80% of fledging age (approximately 22 days) they were banded, weighed, and measured (wing cord, seventh primary). Mist nets were placed directly in front of occupied nest boxes to catch male saw-whet owls when they returned to the boxes. They were identified as males by the lack of brood patch and by their weight. The males were banded, weighed, and measured (wing cord, seventh primary). Young were weighted and measured at fledging.

Diet.--During weekly nest box checks, intact pellets were removed from nest boxes and the surrounding areas. These pellets are being analyzed to determine dietary habits.

Partially consumed or unconsumed prey items were removed from the box, identified (using a field guide), and weighed. Heads and legs of the prey items were removed to avoid duplicate counts, and the rest of the body was returned to the box.

When nesting was complete, all remaining nest box material and pellet fragments were collected. This material was soaked in 10% NAOH to dissolve the hair (Marti 1987). All skulls, jaw fragments, and leg bones were collected and are being identified and enumerated.

Roost site.--During weekly nest box checks the immediate area surrounding the nest box (approximately 15 m in all directions) was carefully checked for roosting adult owls.

■ RESULTS

Nest box use.--Northern saw-whet owl nest box occupancy peaked on 14 March at

SRBOPA, and 10 May at DFNWR (Table 1). The later peak date at DFNWR was attributed to the fact that some of the boxes were not checked prior to this date. Peak occupancy dates for western screech-owl at SRBOPA was 14 March, and at DFNWR it was 22 March (north side) and 15 March (south side). American kestrel nest box occupancy peaked on 9 May (SRBOPA), 31 May (DFNWR, north side), 26 April (DFNWR, south side), and 24 May (Cascade Reservoir).

Species found most often in nest boxes at the 3 study areas were: northern saw-whet owls, western screech-owls, wood ducks, American kestrels, European starlings (*Sturnus vulgaris*), and unidentified squirrels, bees, and wasps (Figs. 4, 5, and 6), with the number of species occupying a nest box ranging from 0 to 3 species (Fig. 7). Cascade Reservoir had the largest percentage (42%) of boxes unoccupied, but that was expected because boxes were in place for such a short period.

Breeding biology.--Clutch size averaged 6.3 eggs in SRBOPA (Table 2). DFNWR's 2 monitored occupied nest boxes had a average clutch of 5. Hatching success was 55% (22 of 40 eggs) for SRBOPA and 81% (9 of 11 eggs) for DFNWR. At SRBOPA 63% of the nestlings (14 of 22) reached fledging age. At DFNWR 9 of the nestlings reached fledging age. Productivity (young per occupied nest box) for SRBOPA was 2 (14 young from 7 occupied boxes) and 2.25 for DFNWR (9 young from 4 attempts). Two of the occupied boxes (1 at SRBOPA and 1 at DFNWR) failed due to the death of 1 of the adults. The causes of the other nest failures were unknown. One northern saw-whet owl nesting attempt in this study may have failed due to human disturbance,

Table 1. Number of occupied boxes at Snake River Birds of Prey Area (SRBOPA), Deer Flat National Wildlife Refuge (DFNWR), and Cascade Reservoir, in Idaho, during 1992. See Appendix A for code names.

STUDY AREA	DATE OF VISIT (JULIAN)	SPECIES USING NEST BOXES								
		NSO	WSO	AMK	NFL	SQU	WDK	BEE	EST	WRT
SRBOPA	42	-	9	-	-	-	-	4	-	2
	56	4	12	-	-	1	-	4	-	1
	74	7	15	-	-	-	-	3	-	1
	88	7	15	-	-	-	-	3	-	1
	102	5	13	2	-	1	-	3	-	1
	116	3	13	1	-	-	-	3	-	1
	130	3	13	3	-	-	-	3	-	1
	144	1	12	3	-	-	-	3	-	-
	158	-	12	2	-	-	-	3	-	-
DFNWR										
	North Side									
	65	-	3	-	-	2	2	-	-	-
	82	-	5	-	-	2	2	-	-	-
	96	-	2	-	-	2	-	-	-	-
	124	-	-	2	1	-	7	-	1	-
	137	-	-	2	-	-	4	1	-	-
	152	-	-	3	1	2	6	1	-	-
	164	-	-	1	1	4	9	1	-	-
	South side									
	61	-	-	-	-	-	-	5	-	-
	75	2	2	-	-	-	-	5	-	-
	89	1	5	-	-	-	-	5	-	-
	103	1	4	1	-	1	1	5	-	-
	117	1	4	1	1	-	10	5	-	-
	131	3 ^a	4	1	1	-	16	5	-	-
	145	-	3	1	2	-	15	5	-	-
	159	-	-	-	-	-	3	5	-	-
CASCADE	100 ^b	-	-	-	-	1	-	-	-	-
	117	-	-	-	-	2	-	-	13	-
	131	-	-	1	1	1	-	5	5	-
	145	-	-	5	3	1	-	6	3	-
	158	-	-	5	2	-	-	2	-	-
	172	-	-	5	1	-	-	1	-	-

^a This includes 2 nest boxes that had been excluded from the checks prior to this date.

^b Nest box checks were started before this date but no boxes were used.

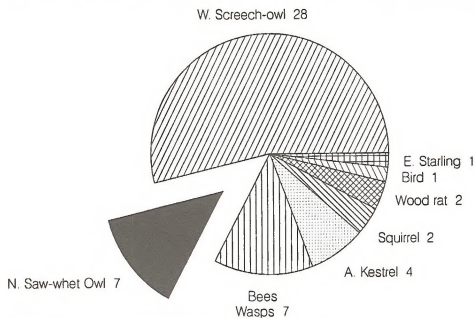


Fig. 4. Number of nest boxes used by all species at Snake River Birds of Prey Area (SRBOPA), southwestern Idaho, 1992.

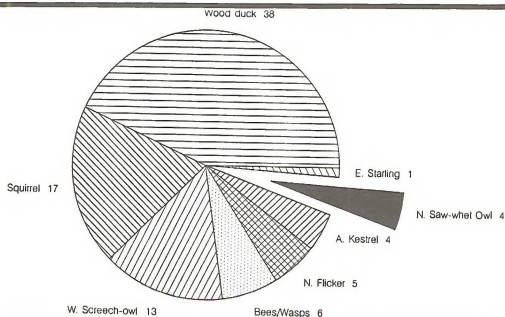


Fig. 5. Number of nest boxes used by all species at Deer Flat National Wildlife Refuge (DFNWR), southwestern Idaho, 1992.

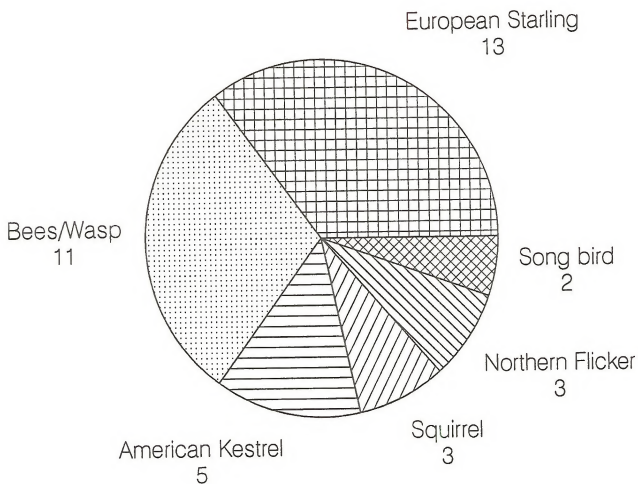
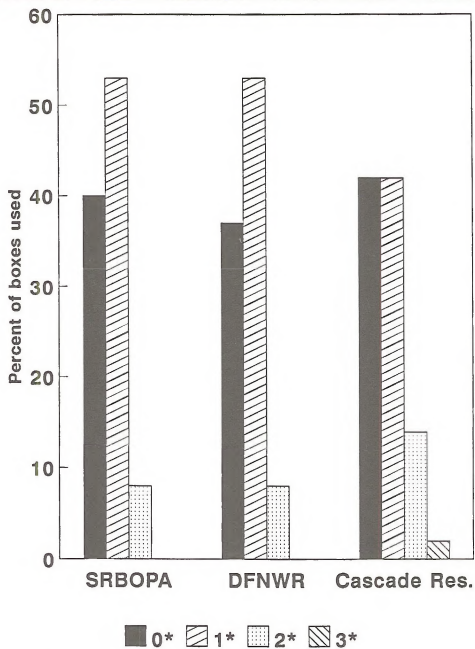


Fig. 6. Number of nest boxes used by all species at Cascade Reservoir, westcentral Idaho, 1992.



* number of species using nest box

Fig. 7. Percent of nest boxes occupied by more than 1 species at Snake River Birds of Prey Area (SRBOPA), Deer Flat National Wildlife Refuge (DFNWR), and Cascade Reservoir, 1992.

Table 2. Nesting Success, clutch size, and number of young fledged for northern saw-whet owls in nest boxes in the Snake River Birds of Prey Area (SRBOPA) and Deer Flat National Wildlife Refuge (DFNWR), 1992.

Site Name	Nesting Success ^a	Clutch size	No young Fledged
<u>SRBOPA</u>			
Three Forks	Successful	6	5
Delta West	Unsuccessful	6	0
Bruneau Marsh North	Unsuccessful	2 ^b	0
Little Valley School	Unsuccessful	6 ^c	0
Jacks Creek	Successful	8 ^c	5
Strike Camp Treeline	Successful	5	4
Orcutt Treeline	Unsuccessful	7 ^c	0
<u>DFNWR</u>			
E-11	Successful	5 ^c	5
10	Successful	5 ^d	4
14	Unsuccessful	1 ^b	0

^a A nest was considered successful if 1 or more young reached 80% age of fledging.

^b Incomplete clutch, was not included in average clutch size calculations.

^c Clutch size determined from a count of young and eggs.

^d Nest was not monitored throughout egg laying, this number may not be accurate.

however there was also a great horned owl using the same grove of trees as this pair of saw-whet owls.

Five adult saw-whet owls, 3 males and 2 females, were captured and banded in the

SRBOPA. Of these 3 females were weighed and measured. Two adults, 1 male and 1 female, were also captured at DFNWR, banded, and measured. All surviving fledglings (14 in the SRBOPA, and 10 in the DFNWR) were banded, and most were weighed and measured (Table 3).

Table 3. Weights and measurements of all northern saw-whet owls (*Aegolius acadicus*) banded at Snake River Birds of Prey Area (SRBOPA) and Deer Flat National Wildlife Refuge (DFNWR), southwest Idaho, 1992.

Band number	Sex ^a	Location	Age ^b	Weight (g)	Seventh primary (mm)	Wing cord (mm)
554-37276	F	SRBOPA	A	112	-	138
554-37277	F	SRBOPA	A	126	106	152
554-37278	F	DFNWR	A	110	101	139
554-37279	M	SRBOPA	A	-	-	-
554-37280	U	DFNWR	L	48	34	65
554-37281	M	SRBOPA	A	70	98	135
554-37282	U	SRBOPA	L	115	-	-
554-37283	U	SRBOPA	L	95	-	-
554-37284	U	SRBOPA	L	99	-	-
554-37285	U	SRBOPA	L	101	-	-
554-37286	U	SRBOPA	L	96	-	-
554-37287	U	SRBOPA	L	-	-	-
554-37288	U	SRBOPA	L	-	-	-
554-37289	U	SRBOPA	L	-	-	-
554-37290	U	SRBOPA	L	-	-	-
554-37291	M	SRBOPA	A	79	-	141
554-37292	U	DFNWR	L	86	51	91
554-37293	U	DFNWR	L	85	67	120
554-37294	U	DFNWR	L	83	63	96
554-37295	U	DFNWR	L	82	54	91
554-37296	M	DFNWR	A	70	100	139
554-37297	U	SRBOPA	L	105	71	112
554-37298	U	SRBOPA	L	100	55	82
554-37299	U	SRBOPA	L	40	-	-
554-37300	U	SRBOPA	L	106	47	76
614-52101	U	SRBOPA	L	98	64	97
664-94504 ^c	U	DFNWR	L	-	-	108
664-94505 ^c	U	DFNWR	L	-	-	107
664-94506 ^c	U	DFNWR	L	-	-	80
664-94507 ^c	U	DFNWR	L	-	-	108

^a Sex of owl determined by presence or absence of brood patch, male (M), female (F), or unknown (U).

^b Age of owl, adult (A), or local bird to young to fly (L).

^c Banded by Al Larson, Golden Eagle Audubon Society.

Some weights and measurements were not obtained because field assistants banded the owls.

Diet.--Of the prey items found in the nest boxes 68% ($n = 48$) were either headless or

half of a body (always the back half). The remaining 32% ($n = 23$) were found intact. Prey items identified were: deer mice (*Peromyscus maniculatus*), house mice (*Mus musculus*), and montane voles (*Microtus montanus*) (Table 4). Pellets and pellet fragments are now being analyzed.

Roost site selection.--After 5 hrs of intensive searching (10 min at each nest box, once a week) no roost sites were located.

■ DISCUSSION

No roost sites were located in 1992. It might have been possible to locate them if more time was spent in the nest box area, but longer visits could be detrimental to nesting success. In several cases the female flew from the nest box and did not return to it while I was in the area. For this reason I stopped looking for roost sites after 10 min. To find roost sites adequately and without bias, owls should be radio tracked (G. Hayward, Colorado State University, pers. commun.).

■ PLANS FOR NEXT YEAR

The 1993 investigation will have the same objectives as 1992. Differences in the microhabitat surrounding each nest box may influence which nest boxes are used by saw-whet owls. To identify these differences, habitat characteristics will be measured in 1993 at all nest boxes occupied by saw-whet owls within the past 3 years and at randomly selected unoccupied boxes. Habitat characteristics to be measured will include but will not be limited to: species and condition of nest box tree, stand density, canopy cover, ground cover, aspect and slope of nest box, elevation, and distance from nest box to nearest forest opening, permanent water source, agricultural field, road, and other occupied nest boxes.

Table 4. Prey items found in northern saw-whet owl nest boxes at Snake River Birds of Prey Area (SRBOPA) and Deer Flat National Wildlife Refuge (DFNWR), southwest Idaho, 1992.

	# found	Average weight(g)	n	Weight range(g)
SRBOPA				
<i>Peromyscus</i>	28	14.2	4	10.0 -19.0
<i>Mus</i>	32	9.5	3	6.0 -12.0
<i>Microtus</i>	2			
Unknown	9 ^a			
DFNWR				
<i>Peromyscus</i>	12	19.2	5	16.5 - 24.0
<i>Mus</i>	0			
<i>Microtus</i>	7	11.2	6	5.5 - 15.5
Unknown	10 ^a			

^a Prey items were not identified at nest box checks during egg laying.

Distances will be measured with a measuring tape or estimated from topographical maps and/or aerial photos. Canopy cover will be measured in the winter (when adults select nest boxes) using a spherical densitometer. Ground cover will be measured at 50 points uniformly distributed within a 100 m radius of nest box using a technique created by J. Smallwood (Univ. of Florida, pers commun). Given the small number of nesting owls radio transmitters may be placed on some adults and immature saw-whet owls to aid in roost site location.

■ ACKNOWLEDGMENTS

This study could not have been completed without the support, help, and friendship of John Doremus. Permission to access nest boxes was given by Dick Orcutt, C.J. Strike Wildlife Management Area, and Kevin Ryan,

Deer Flat National Wildlife Refuge. I am thankful for the field assistance of Diane Evans, David Sellars, Al Larson, Rick Olendorff, Dale Thompson, Dean Barnard, and Jerry Lancaster. A lot of help and advice came from Marc Bechard, Jim Munger, Carl Marti, Wayne Melquist, Karen Steenhof, Mike Kochert, Bob Lehman, Jim Messerli, Matt McCoy, Chris Woods, Tim Carrigan, Jeff Marks, and Greg Hayward. Labor in building and erecting nest boxes came from many friends. My greatest support was Dave, Laurel, and Niki Chmielowiec.

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Appendix A. Three letter codes, common and scientific names listed in Figures 1, 2, 3, and 4.

CODE	COMMON NAME	SCIENTIFIC NAME
AMK	American kestrel	<i>Falco sparverius</i>
BEE	Unidentified bees and wasps	
EST	European starling	<i>Sturnus vulgaris</i>
NFL	Northern flicker	<i>Colaptes auratus</i>
NSO	Northern saw-whet owl	<i>Aegolius acadicus</i>
SQU	Unidentified squirrel	
WDK	Wood duck	<i>Aix sponsa</i>
WRT	Bushy-tailed woodrat	<i>Neotoma cinerea</i>
WSO	Western screech-owl	<i>Otus kennicottii</i>

Nest Box Use in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*Roosting or breeding raptors used boxes at 29 of 43 available sites in 1992. Western screech-owls (*Otus kennicottii*) used 26 sites and bred at 13. Increased numbers of breeding screech-owls and high success rates may be related to prey populations in the area.*

▪ OBJECTIVES

To determine patterns of nest box use, fidelity to site and mate, reproductive success, food habits and the annual body mass in western screech-owls.

▪ METHODS

Eighty nest boxes were available at 43 sites for raptor roosting and nesting as of April 1992. (One box was destroyed by fire in late March.) Nest boxes were visited monthly November-May and October-December. Boxes with breeding screech-owls were visited during the first week of May to band nestlings. Western screech-owls were captured throughout the year in

boxes. All adult-size owls were weighed with a Pesola 300-g spring scale, and unbanded owls were banded. After fledging all prey remains were removed from the boxes for food habits analysis.

▪ RESULTS

Western screech-owls used 26 of 43 sites available during 1992 (Table 1). Thirteen of the 26 sites were used for breeding attempts. Of the 13 sites used for breeding, 8 were successful and 5 were undetermined success. We banded 50 young at or near fledging age at 11 sites. Two nestling screech-owls died when their bands became entangled in a piece of unraveled carpet material. The carpet material was placed in the box between the floor and the entrance hole to

Table 1. Location and status of roosting/nesting boxes in the Snake River Birds of Prey Area, 1992.

Location Name	Status	Nesting Success
Black Butte, Lower	WSO roosting	-
Black Sands III	Vacant	-
BPNA East Boundary	WSO breeding	Unk success
Bruneau Boat Launch	WSO roosting	-
Bruneau Marsh	WSO roosting	-
Bruneau Marsh North	WSO roosting/NSO breeding	-/Unsuccessful
Bruneau Marsh South	WSO breeding/Amk breeding	Unk Success/Unk Success
Bruneau Marsh West	WSO roosting	-
Bruneau River	WSO roosting	-
Bruneau River Bridge	Vacant	-
Bruneau River Bridge West	Vacant	-
Bruneau River South	Vacant	-
Bruneau River West	Vacant	-
Bruneau West Marsh	Vacant	-
Bruneau West Marsh South	WSO roosting	-
Cabin	WSO breeding/Amk breeding	Successful/Unk Success
Castle Creek Mouth North IV	WSO breeding/Amk breeding	Unk Success/Unk success
Cellar Hole	WSO breeding	Unk Success
Crane Falls Lake	WSO breeding	Successful
Crane Falls Sturgeon	WSO breeding	Successful
Delta East	WSO breeding	Unk Success
Delta South	Vacant	-
Delta West	WSO roosting/NSO breeding	-/Unsuccessful
Gravel Pit	WSO roosting	Nonbreeding
Harris	WSO roosting/AmK breeding/AmK breeding	-/Unk Success/Unk Success
Jacks Creek	NSO breeding	Successful
Little Valley School	WSO roosting/NSO breeding	-/Unsuccessful
Loveridge Bridge	Vacant	-
Orcutt Treeline	WSO roosting/NSO breeding	-/Unsuccessful
Rabbit Springs	WSO breeding	Successful
River Road	WSO breeding	Successful
Strike Camp	NSO breeding	Successful
Strike Camp Treeline II	WSO breeding	Successful
Strike Dam	Vacant	-
Strike Dam Marsh	Vacant	-
Strike Ditch	Vacant	-
Strike Reservoir	WSO breeding	Successful
Three Forks	NSO breeding	Successful
Three Forks North	Vacant	-
Three Forks South	Vacant	-
Three Forks West	Vacant	-
Tom Draw	WSO breeding	Successful
Two Forks	WSO roosting	-

facilitate movement of adults and young out of the box.

American kestrels (*Falco sparverius*) attempted to nest in 5 boxes at 4 sites. The success of the kestrel nesting attempts is not known.

Seventy-five screech-owls (50 nestlings and 25 adults) were banded during the 1992 field season.

Seventy-nine screech-owl body mass measurements were obtained from adult-size owls. Twenty-two female body mass measurements taken outside the breeding period ranged from 192-247 g. Five female screech-owl mass measurements taken during the breeding period ranged from 250-287 g. Five male screech-owl body mass measurements ranged from 154-217 g, and mass of 59 owls of unknown sex ranged from 163-252 g.

No body mass measurements were obtained from American kestrels, and no kestrels were banded in 1992.

Data on northern saw-whet owls (*Aegolius acadicus*) using nest boxes in the study area are reported in Rains this volume.

Ten new sites were added in 1992. Five of these sites had boxes with entry holes too small for screech-owls. I abandoned 2 traditional sites and removed the boxes.

■ DISCUSSION

The increase in breeding screech-owls and their success at raising young to banding age is probably due to high numbers of small mammals available in the study area. There has been no evidence of owls changing sites or mates. Body mass measurements for 1992 are within the range of measurements found in the past.

■ PLANS FOR THE 1993 FIELD SEASON

The study area will be expanded to include land recently purchased by the Idaho Fish and Game Department in the Bruneau River valley. More nest boxes will be placed in the study area to attempt to attract saw-whet owls. Carpeting material will be removed from the boxes. Study objectives will remain the same as in 1992.

■ ACKNOWLEDGMENTS

I thank "Charlie" Rains and Rick Olendorff for their help in establishing new sites and monitoring sites during 1992. I thank Dick Orcutt for allowing Charlie, Rick, and myself access to the C. J. Strike Wildlife Management Area.



Feeding Ecology of the Barn Owl in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

Surveys of 15 traditional barn owl nest/roost sites revealed evidence of roosting at 7 sites, but nesting at only 3 sites (2 concentrations on Black Butte and 1 other site). Diet data revealed pronounced changes in several major prey, most notable of which were the 14% decline in voles and 13% increase in gophers.

▪ OBJECTIVE

To determine food-niche parameters and food-niche variation among collection sites and among years for barn owls (*Tyto alba*) nesting in the Snake River Birds of Prey Area (SRBOPA).

▪ METHODS

Owl diet data originated from regurgitated pellets that I collected at cliff sites occupied by barn owls. Most sites were occupied by barn owl nests. All collections were made from March to August. Prey in the pellets were identified and quantified by standard methods (Marti 1987). See Marti (1988) for treatment of data from earlier years.

▪ RESULTS AND DISCUSSION

Pellet samples were collected at 4 sites in 1992. Collection locations and sample sizes are given in Table 1. The 1992 dietary sample is summarized in Table 2. Voles (*Microtus montanus*) declined in barn owl diets by 14% from the preceding year, thus repeating the pattern of vole dietary peaks occurring every 4-5 years. See Marti (1991) for diet trends beginning in 1978. Several other major prey increased in the diet sample from the 1990 frequencies. Most striking was the 13% increase in *Thomomys townsendii*.

Evidence of use was found at 7 sites in 1992, but nesting was documented at only 3

Table 1. Collection sites for barn owl diet data and number of prey in collection samples from the SRBOPA, 1992.

Collection Site	Number of Prey in Samples	
	29 February	6 June
Castle Rock Cave		137
Lower Lower Black Butte	63	321
Upper Lower Black Butte	254	915
Garbage Draw	38	213

areas. One of these was a single pair, but the other 2 were concentrations of nesting barn owls at Black Butte. One group may have contained as many as 5 pairs and the other had 2 pairs. See Marti (1990, 1991) for comparisons of the number of occupied sites and size of diet samples in other years.

■ PLANS FOR 1993

Three trips to the SRBOPA are planned for the spring/summer of 1993. The objectives for 1993 are to continue collecting food habits data for the analysis of long-term predation trends by barn owls and to monitor trends in breeding numbers of barn owls.

■ ACKNOWLEDGMENTS

I thank Richard Olendorff, Michael Kochert, Karen Steenhof, John Doremus, Gerry Griggs, and all of the Snake River Birds of Prey Research staff for a variety of assistance in carrying out this study. The Bureau of Land Management provided a vehicle for field use and living space in field camps. Weber State University provided a Faculty Research Grant covering travel to the study area from Ogden, Utah, and laboratory space and computer facilities for data analysis.



Table 2. Total prey identified for the barn owl in the SRBOPA, 1992.

Prey Species	Number	Percent Number
MAMMALS		
<i>Sorex vagrans</i>	5	0.3
<i>Sylvilagus nuttallii</i> (neo.)	3	0.1
<i>Mus musculus</i>	126	6.4
<i>Peromyscus</i> spp.	252	12.9
<i>Reithrodontomys megalotis</i>	61	3.1
<i>Neotoma lepida</i>	6	0.3
<i>Microtus montanus</i>	950	48.5
<i>Perognathus parvus</i>	12	0.6
<i>Dipodomys ordii</i>	140	7.1
<i>Thomomys townsendii</i> (juvenile)	370	18.9
BIRDS		
<i>Sturnus vulgaris</i>	7	0.4
unidentified icterid	2	0.1
unidentified medium bird	4	0.2
unidentified small bird	3	0.1
Totals	1941	100

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Wintering and Nesting Site Use by Long-eared Owls in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

I found a total of 26-33 wintering long-eared owls at 7 of 8 sites checked, and captured 24 owls, of which 4 were recaptures. I found evidence of breeding at 6 of 10 sites, for a total of 8 nests. At least 5 nests were successful, branching at least 16 juveniles. During breeding season, I banded 6 juveniles and caught 1 adult male and 2 adult females; both females were recaptures.

▪ OBJECTIVE

To gather long-term demographic data on nesting and wintering long-eared owls in the Snake River Birds of Prey Area.

▪ METHODS

In the winter, I trapped owls during the day by setting 4-cm mesh mist nets in flight paths within the roosting groves. I either flushed owls back and forth to cause them to fly into the nets, or waited for them to return on their own to their favored roost site. I weighed owls with a 300 or 1,000-g pesola scale, and banded all

unbanded owls. I used coloration of the remiges to determine age: a pink wash on the underside of the wings indicates freshly molted feathers, and thus an adult bird. This characteristic is best early in the winter, and fades later in the season. A more definitive characteristic is 2 tones on the top surface of the remiges, which results from an adult owl only partially molting its remiges during the summer. The old feathers will be paler than the new feathers. If 2 tones are present, the owl is definitely an adult bird; however, I have recaptured some owls which I knew were adults that did not have 2-toned remiges. Thus, an owl with even-toned remiges may be either an adult or a first-year bird.

In the breeding season, I captured and

banded adult owls during the branching or fledgling stages, using mist nets baited with a great horned owl decoy at dusk or night. I set the nets outside the nest grove, in a position so that the great horned owl decoy would be silhouetted against the sky. I weighed all adult owls and determined sex by the presence or absence of a brood patch. I banded young owls during the last week of the nestling period or the first 2 weeks of branching.

■ RESULTS AND DISCUSSION

From 15 December 1991 through 22

February 1992 I checked 8 wintering sites on 6 days and found 26-33 long-eared owls at 7 of the sites (Table 1). The high figure was arrived at by adding the highest number seen at each site and assuming that owls seen at the sites close together (Tom Draw and Massacre Draw; Fossil and No Name Creek Mouths) were different birds. The low number was arrived at by adding the lowest numbers seen, assuming that birds seen at Tom Draw and Massacre Draw on different days were the same birds, and disregarding the owls seen at No Name Creek on 22 February because it was too close to the time when winter roosts break up and new birds could be coming in.

Table 1. Sites where roosting long-eared owls were found during the winter of 1991-92 in the SRBOPA. Loveridge Bridge was also searched, and no owls were found.

SITE	DATE	# SEEN	# Banded	# RECAPTURES
Tom Draw	15 Dec	0-1	---	---
Tom Draw	26 Jan	4	3	1
Massacre Draw	15 Dec	3	---	---
Castle Creek Mouth N	20 Jan	3-4	3	0
Nahas Marsh	26 Jan	10-11	7	1
Crane Falls Sturgeon	9 Feb	1	1	0
Fossil Creek Mouth	17 Feb	2	1	1
No Name Creek Mouth	17 Feb	4-6	0	0
No Name Creek Mouth	22 Feb	8	5	1

I captured 24 of these owls, 4 of which were recaptures (Table 2). Two of the 4 recaptures were owls that I had caught at other nearby roosts in the winters of 1989-90 and 1990-91; 1 was an owl I had banded at a nearby roost the previous month; and the fourth owl I had banded at the same site the previous winter. These recaptures showed more movement among winter roost sites than my previous data had disclosed, probably because most of my previous captures and recaptures had been from Tom Draw. Numbers of long-eared owls wintering in the SRBOPA in 1991-92 appeared lower than the previous winter, when I found at least 52 owls in the same sites (except Nahas Marsh).

Tom Draw had few owls this winter, although it has been the most reliable site for wintering long-eared owls since 1988

and had ≥ 30 owls the previous winter. On my first visit there we flushed only 1 possible long-eared owl (a companion got an obstructed glimpse of the bird). I checked Massacre Draw which is about 0.8 km upriver of Tom Draw and which I had never checked before; I found 3 owls there but did not attempt to trap them. I thought it possible that the Tom Draw long-eared owls had switched to a roost across the river at Nahas Marsh, because they have used different roost sites at Tom Draw both within a season and among seasons. Land access to Nahas Marsh is through private land, so I had never checked it in other winters. On the second visit, we went by boat from Swan Falls Dam so that we could check both Tom Draw and Nahas Marsh on the same day. We found 10-11 owls at Nahas Marsh and 4 owls at Tom Draw.

Table 2. Recaptured long-eared owls from January 1988-June 1992 in the SRBOPA.

LOCATION	BAND NUMBER	SEX	DATES CAPTURED (WT. IN GRAMS)
Castle Creek Mouth N	816-44041	?	Apr 87 (juv); Jan 91 (281)
Tom Draw	896-36733	M	Jan 88 (271); May 89 (231); Dec 90 (245); May 91 (228)
Tom Draw	896-36734	?	Jan 88 (272); Jan 89 (248)
Tom Draw	896-36735	M	Jan 88 (276); Jan 89 (252); May 90 (240)
Tom Draw	816-74512	?	May 88 (268); Jan 89 (252)
Tom Draw	816-74592	?	Dec 89 (248); Dec 90 (268)
Tom Draw	816-74599	?	Dec 89 (249); Dec 90 (282)
Tom Draw	816-74909	?	Dec 90 (249); Feb 91 (250)
Tom Draw	816-74595	?	Dec 89 (241); Jan 92 (265) - at Nahas Marsh
Castle Creek Mouth N	816-74922	F	Jan 91 (>288); May 92 (292)
Fossil Creek Mouth	816-74927	?	Feb 91 (277); Jan 92 (250) - at Tom Draw
Fossil Creek Mouth	816-74929	M	Feb 91 (272); May 91 (219) - at Castle Ck Mouth N
Fossil Creek Mouth	816-74931	?	Feb 91 (269); Feb 92 (250)
Castle Creek Mouth N	816-74979	?	Jan 92 (223); Feb 92 (-) - at No Name Creek Mouth
No Name Creek Mouth	816-74998	F	Feb 92 (345); May 92 (323)

During the breeding season, I checked 10 sites and found evidence of breeding at 6 sites containing a total of 8 nests (Table 3). I saw 16 banded juveniles at 4 sites, from 5 or 6 different nests. I banded 7 juveniles and captured 3 breeding adults, 2 of which were recaptures. Both recaptures were females: the first had wintered at the same site in the winter of 1990-91, and the second apparently wintered at the same site (No Name Creek mouth) that year. These are my first records of females which had wintered and bred in the same site; previously my only certain such records

were of males. The second female I had first trapped at No Name Creek Mouth on 22 February, 1992. This late winter capture date makes it possible that she had already moved there to breed from somewhere else; 22 February is about when winter roosts break up and owls begin to move and form pairs. However, because there were 6-8 long-eared owls at the mouths of Fossil and No Name Creeks the previous week (these sites are 0.4 km apart), it seems most likely that the female had wintered at that site.

Table 3. Nests of long-eared owls in the Snake River Birds of Prey area in 1992. Other sites searched with no nests found are: Strike Dam Road, Rabbit Springs, Fossil Creek Mouth, and Sinker Creek mouth.

SITE	ADULTS TRAPPED	# YOUNG	# JUV BANDED	FATE
Strike Dam Marsh	---	≥2	0	unsuccessful (2 juv depredated)
Strike Dam Marsh West	---	?	---	unsuccessful ^a
Castle Creek Mouth N I	1(F)	≥2	2	successful ^b
Castle Creek Mouth N II	0	≥4	1	successful
No Name Creek Mouth	1(F)	≥4	4	unknown, probably successful ^c
Tom Draw	---	?	---	unknown ^d
Tom Draw I	1(M)	≥4	0	successful
Nahas Marsh	---	≥2	0	successful

^a J. Doremus found an incubating owl; on rechecking, I found no young or used nest but 1 adult was present.

^b Six adult owls flew at the great horned owl decoy at once, so it is possible there was a third nest or attempt at this site. I assumed the 1 female I caught was the mother of the youngest owlets, and assigned owlets to the official SRBOPA nest site that they were closest to when found as branchers.

^c One newly branched owlet and 3 owlets in the nest at banding time.

^d I could not determine whether the 4 flying juveniles that I saw were from 1 or both Tom Draw nests.

The No Name Creek female weighed 345 g on 22 February and 323 g on 16 May. Hers was the heaviest of 115 long-eared owl weights I have recorded, the next greatest weight being 328 g. Ninety percent of long-eared owls in the SRBOPA weigh between 240 and 290 g during the winter, with a median of 265 g. It seems likely that she was near the height of gonadal development in late February, and that she had been the recipient of courtship feeding.

Since January 1988 I have banded 207 long-eared owls (24 breeding adults, 75 wintering adults, and 108 local juveniles) and recaptured 15 owls a total of 18 times (Table 2). Of the recaptures, 7 owls were caught in more than 1 winter at the same site, 2 owls were caught at different sites in different winters, 1 owl was caught at 2 different sites in the same winter, 5 owls were caught as adults in both the nesting and winter seasons at the same site, and 1 owl was captured as a nestling and wintering adult at the same site.

■ PLANS FOR 1992-93

I plan to continue monitoring, trapping, and banding long-eared owls at as many sites as I can each winter and nesting season. Priority sites will be the ones where I trapped in previous winters and springs.

■ ACKNOWLEDGMENTS

I thank John Doremus for consistently providing help, knowledge, and support for this work. I thank the many other people who helped tote poles and trap owls this year: Pam, Roger, Conrad, and Lauresta Ruth; Peter and Kelsey Harrity; Signe Sather-Blair; Bruce Zoellick; Jim and Vicki Clark; Brian Schaeffer; Beth Workman; and Gary Shue. The Boise Field Office of the U.S. Fish and Wildlife Service donated the use of a jet boat.



Exploitation of Carcasses by Common Raven in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We observed common ravens (*Corvus corax*) foraging on carcasses to determine how and why groups assemble. Carcasses were discovered by singletons or small groups, but the number of ravens exploiting a carcass quickly grew to an average of 10. Groups were formed primarily by local enhancement; recruitment from roosts was rare. Ravens found carcasses by cuing on other ravens, and more importantly, by cuing on black-billed magpies (*Pica*) and golden eagles (*Aquila chrysaetos*). Territorial pairs rarely defended carcasses, and groups may form to reduce each individual's neophobia. Ravens feeding in the SRBOPA appear to be less vocally conspicuous than ravens feeding in the boreal forest. Reciprocity and indirect selection may be of little significance to the evolution of group foraging because tagged juveniles do not appear to form stable alliances with their siblings or other ravens.*

OBJECTIVES

1. Determine if ravens search for food singly or in groups and determine the importance of other scavengers and predators in alerting ravens to the location of a carcass.
2. Determine the relative roles of local enhancement and recruitment from roosts in the attraction of ravens to carcasses.
3. Determine if carcass size influences the relative importance of local enhancement and recruitment from roosts.
4. Determine if discoverers of carcasses defend them.
5. Determine the ages of ravens foraging on carcasses.

6. Determine if siblings forage together.
7. Record the ontogeny of raven vocalizations.

■ INTRODUCTION

In forested areas of the northern hemisphere common ravens accumulate into large crowds at carcasses of animals (Coombes 1948, Davis and Davis 1986, Bruggers 1988, Heinrich 1988). These groups form by a combination of attraction to vocalizations at the carcass and recruitment from distant nocturnal roosts (Heinrich and Marzluff 1991, Marzluff and Heinrich 1991, Heinrich et al. in press). Recruitment from roosts is the more important process in group formation as local attraction cannot explain the accumulation of large numbers of birds at a carcass. The vast majority of ravens that congregate at carcasses are young, vagrant birds (Coombes 1948, Bruggers 1988, Heinrich 1988, Skarphedinsson et al. 1990). Group foraging is beneficial to these vagrants because only gangs of 9 or more birds can overpower the dominant territorial adults (Marzluff and Heinrich 1991).

Do ravens in desert environments behave in a similar manner? We began to investigate this question in 1991 by studying the formation of crowds at carcasses placed in the Snake River Birds of Prey Area (SRBOPA). The SRBOPA provides a stark contrast to the boreal forest of Maine; the shrub steppe vegetation and infrequent snow should enable ravens to easily locate the numerous small (black-tailed jackrabbits [*Lepus californicus*]) and large (sheep) mammal carcasses. In the north woods the situation is very different; carcasses are well hidden, patchily distributed and quickly

covered by frequent snows. This is a key to the evolution of recruitment from nocturnal roosts; reciprocated sharing of information at roosts may be the best way for individuals to indirectly search the vast areas necessary to discover sparse, but rich, food bonanzas (Ward and Zahavi 1973).

Ravens in the SRBOPA assemble into crowds, just as observed in Maine. However, we predict that crowds in the SRBOPA are formed primarily by ravens independently discovering carcasses or cuing on local signals from others at the carcass. We do not expect individuals to share information at roosts for several reasons: (1) Roosts are huge, often numbering in the hundreds of individuals (Engel and Young 1992, Engel et al. 1992). Attraction of such a large number of ravens to a carcass would likely result in intense competition that would lower an individual's food intake (Marzluff and Heinrich 1991). (2) Individuals searching the open shrub country could easily spot carcasses, especially by noting the presence of the conspicuous black-billed magpies. (3) Predictable foods such as grains and feedlot offal provide a substantial portion of ravens' diets in the SRBOPA (Engel and Young 1989). Therefore, a raven that does not succeed at finding a carcass may simply return to a reliable food source the next day rather than depend on others discovering a carcass and informing it of the location.

■ METHODS

We observed free-flying ravens opportunistically as we travelled throughout the SRBOPA. The number of free-flying birds per group was recorded whenever ravens were seen to document the average

group size of ravens flying at large. These observations were made around carcasses, nesting areas, and on flight lines to and from communal roosts. Maximum feeding group size was also recorded opportunistically; the number of ravens feeding at any carcass was counted.

We placed carcasses in the field and watched them continuously until they were discovered by ravens. Discovery was inferred if a raven landed by the carcass and approached it or, more commonly, when a flying raven hovered above the carcass or circled it from an altitude of less than 10 m. Carcasses were watched after discovery for varying lengths of time. Some jackrabbits were placed in the field and surrounded with leg-hold traps to capture golden eagles. These were watched until the traps were triggered or removed at the end of 1 day. Jackrabbits, deer and sheep carcasses were also placed in the field solely to watch raven foraging. Ravens using these carcasses were observed continuously until feeding began and sporadically thereafter. Observations were made for several hours each morning and on and off throughout the day to determine changes in group size during a day versus from 1 day to the next.

Feeding rates and several behaviors were documented when ravens or magpies visited a carcass. Scan samples were taken at random approximately every hour throughout an observation period. The behavior of each magpie and raven was classified at this time. Focal samples were conducted to quantify feeding and fighting rates. Feeding rates were defined as the amount of time a focal animal was eating or on the carcass during a 30-min observation period. Fighting rates equalled the number of aggressive

encounters a focal animal engaged in during a 5-min observation period.

We opportunistically searched for occupied raven nests throughout the SRBOPA. Cliff and ground nests were entered when the nestlings were approximately 3 weeks old. Each nestling was weighed, its culmen was measured, and it was tagged with a uniquely numbered patagial tag on 1 wing and a U.S.F.W.S. band on 1 leg. Nests were visited just prior to and after fledging, when possible, to determine productivity. Movements of tagged juveniles were documented by a variety of personnel during routine field work. Permanent biologists from Greenfalk Consultants drive through the study area nearly every day and were instructed to report sightings of marked ravens to us.

Three ravens were brought into captivity during the 1992 breeding season. Two of these birds were of fledging age, but could not leave their nest because of human interference. The third was 1 month post-fledging and had a broken leg. All 3 birds were housed in a 4 x 4 x 3-m aviary and fed a variety of animal and vegetable matter. Their vocalizations were recorded with a Sennheiser ME-80 microphone and a Marantz PMD221 tape recorder. Recordings were made at approximately monthly intervals or whenever a new vocalization was heard.

■ RESULTS

Discovery and Buildup of Ravens at Carcasses

Ravens were most commonly observed flying singly or in small groups (Fig. 1A).

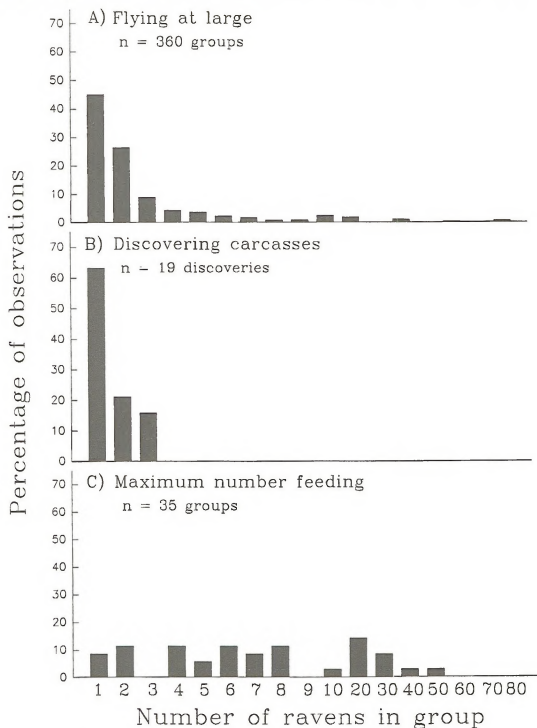


Fig. 1. Number of ravens in groups observed flying at large (A), discovering carcasses (B) and feeding at carcasses (C).

Observations of up to 70 ravens flying as a group were made, but most large groups represented birds entering or leaving communal roosts. However, occasionally groups of 30-50 were seen soaring and traveling during the middle of the day. Most carcasses were discovered by single ravens (Fig. 1B; \bar{x} discovering party size = 1.5, $n = 19$, $SD = 0.77$), but groups eventually assembled to share the carcass (Fig. 1C). On average, 10.3 ravens fed at each carcass ($n = 35$, $SD = 10.4$), but numbers ranged widely from 4 to 50. Carcass size seemed to have little effect on the eventual number of ravens exploiting food (the maximum numbers of ravens observed were 50 at a jackrabbit and 30 at a deer).

Ravens in Idaho behaved in striking contrast to those previously studied in western Maine. We observed ravens at 35 carcasses and watched 19 (3 large: deer [*Odocoileus hemionus*] and sheep, 16 small: jackrabbits and raccoons [*Procyon lotor*]) intensively for 270 hrs to determine the timing of discovery and subsequent buildup of birds. Carcasses were quickly discovered (\bar{x} time to discover = 123 min after placement in the field, $n = 18$, $SD = 139$), but ravens often waited 1 or more days before feeding on them. Carcasses were fed upon on the day of discovery 11 times (all were jackrabbits; \bar{x} time to feed = 100.5 m after discovery, $SD = 137.2$). Feeding began 1-6 days after discovery on 7 occasions (5 jackrabbits, 1 deer, 1 sheep; \bar{x} time to feed = 1.9 days after discovery, $SD = 1.8$). In 1 case feeding did not occur until 60 days after discovery (a sheep). Two carcasses were never fed upon by ravens: 1 jackrabbit was eaten by northern harriers (*Circus cyaneus*), and 1 was eaten by a golden eagle.

The presence of black-billed magpies at a carcass appeared to facilitate the discovery of a carcass and subsequent feeding by ravens. Magpies discovered 15 of 19 carcasses before ravens and fed before ravens at 11 of 19. Ravens discovered and fed upon carcasses more quickly if black-billed magpies had already discovered the carcass than if no magpies were present (time for ravens to discover carcass with 2 or more magpies: $\bar{x} = 86.1$ m, $SD = 75.9$, $n = 11$; time for ravens to discover carcass without magpies: $\bar{x} = 144.2$ m, $SD = 129.9$, $n = 5$; time for ravens to feed after discovery with 2 or more magpies: $\bar{x} = 155.1$ m, $SD = 244.2$, $n = 11$; time for ravens to feed after discovery without magpies: $\bar{x} = 504.0$ m, $SD = 273.6$, $n = 4$).

The ability of magpies to discover carcasses before ravens and functionally attract other scavengers to a carcass was also evident at 30 jackrabbit carcasses placed in the field to capture golden eagles. Observations at these carcasses prior to triggering of the traps indicated that magpies and occasionally coyotes (*Canis latrans*) discovered carcasses initially, often before sunrise (Fig. 2). Ravens were rarely seen at carcasses before 1 or 2 magpies had already accumulated. Numbers of ravens and magpies increased throughout the morning, peaking at approximately 10:00. It is not surprising that magpies and coyotes were the first scavengers to discover carcasses because they rely upon smell in addition to vision to locate food (Buitron and Nuechterlein 1985). Ravens, and especially golden eagles, are more visually oriented and appear to find many carcasses by cuing in on magpies and coyotes (see also Marzluff et al., this volume).

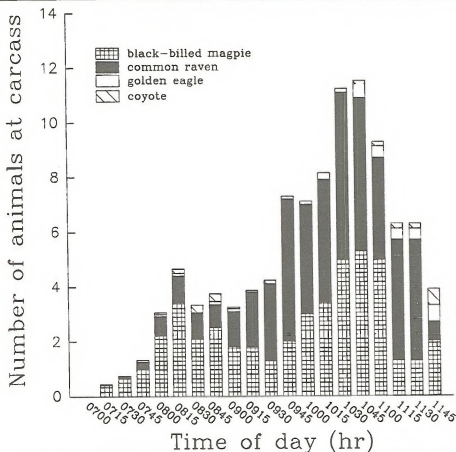


Fig. 2. Build up of scavengers at jackrabbit carcasses. Carcasses were placed in the field to bait traps for golden eagles and observations were terminated when traps were sprung. Observations were made at a total of 30 carcasses, but the time that each carcass was observed varied so that sample sizes for each time interval range from 3 (latest time intervals) to 30 (earliest intervals). The number of animals per interval that is plotted is the average number observed during that time at all carcasses.

Ravens and magpies appear to cue in on foraging golden eagles and attempt to scavenge food from these predators after they make a kill. We observed magpies during 89 eagle hunting forays and observed ravens during 88 eagle forays. Both corvids showed significant numerical responses when eagles captured jackrabbits that were not evident when eagles captured smaller prey or

were unsuccessful (Fig. 3). Half of all successful attacks on jackrabbits attracted ravens; one-third attracted magpies (Fig. 3A). The average number of ravens increased from 1 to 5.1 after a successful attack on a jackrabbit and magpies increased from an average of 2.3 to 3.4 (Fig. 3B,C). The resulting number of corvids attending a successful kill was significantly higher than

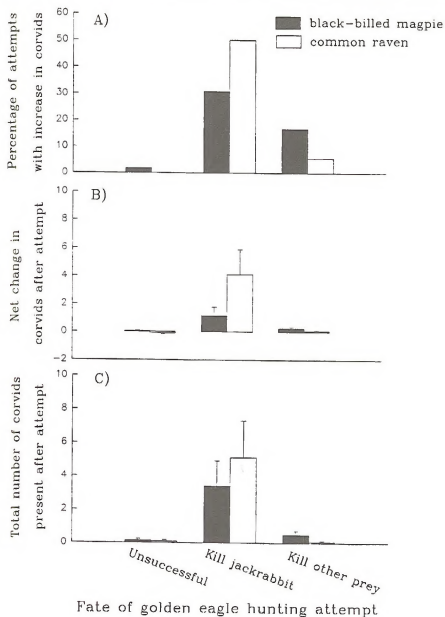


Fig. 3. Change in abundance of corvids after free-ranging golden eagles attempted to capture prey items. Three indexes of change are presented: (A) the percentage of attempts that had an increase in corvids after the attack relative to before the attack, (B) the number of corvids after the attack minus the number before the attack, and (C) the total number of corvids present after the attack. Magpies were observed during 89 hunting forays and ravens were observed during 88 forays.

the number attending a successful kill of a smaller prey item (Townsend's ground squirrel [*Spermophilus townsendii*], rock dove [*Columba livia*], ducks, and reptiles) or an unsuccessful attempt (ravens: $F_{(2,85)} = 16.9$, $P < 0.001$; magpies: $F_{(2,86)} = 11.7$, $P < 0.001$).

The observations of ravens and magpies being attracted to other scavengers and predators presented above suggest that the buildup of ravens at a carcass was primarily by local enhancement. As Figs. 2 and 3 illustrate, 5-8 ravens were commonly attracted to a carcass by local enhancement over the span of a few hours. Throughout an entire day many more ravens were attracted to a carcass. We observed the change in numbers of ravens and magpies at 21 carcasses (Fig. 4). Nearly all the variation in numbers of birds feeding was due to a gradual accumulation of birds during the day (Fig. 4; solid bars). Most changes over night represented the failure of birds to return to a carcass from 1 day to the next (Fig. 4; open bars to the left of the 0, or no change, bar). In 1 case the number of ravens feeding at a deer increased from 3 to 30 overnight suggesting that some recruitment from roosts may occur, but the usual pattern of buildup is for numbers to increase quickly to 5 or 6 after 1 bird begins to feed. This small group then feeds sporadically until the carcass is consumed.

Behavior of Corvids Foraging on Carcasses

Ravens were observed engaged in a variety of behaviors while feeding at a carcass. Sample sizes were too small for statistical analyses at the present time, but some interesting differences were apparent in Fig. 5 and Fig. 6. Roughly 30% of the ravens at

a carcass fed at any given time and this percentage tended to be greatest in groups of 6 or more, especially if magpies were also present (Fig. 5A). Ravens foraging with magpies tended to perch away from food more often than ravens foraging without magpies (Fig. 6A, B). Much of the time spent perching away from food involved ravens waiting to pirate food from magpies as they hauled meat from the carcass to caches (Fig. 5A).

Defense of carcasses by ravens was minimal. In 1 case, an apparent pair of mated adults consistently drove a single immature intruder away from a deer carcass. The immature reacted by giving begging vocalizations and assuming the fuzzy-headed submissive posture (Heinrich 1988). Macho posture displays and escorting, typical defensive behaviors (Marzluff and Heinrich 1991), were most common when group size was largest (Fig. 6D).

Feeding rates of ravens tended to increase with increasing group size (Fig. 7A). Single ravens fed at very low rates, but samples of feeding in large groups are presently insufficient to determine the optimal feeding group size. Samples are also insufficient to determine if feeding rates depend on the presence of magpies.

Feeding rates of magpies tended to decrease with increasing group size (Fig. 7B), which may explain why they rarely were observed in groups of more than 3.

Age of Ravens at Carcasses

Five ravens were captured while approaching jackrabbit carcasses in 1991 and 1992. Three of these birds had pink mouths

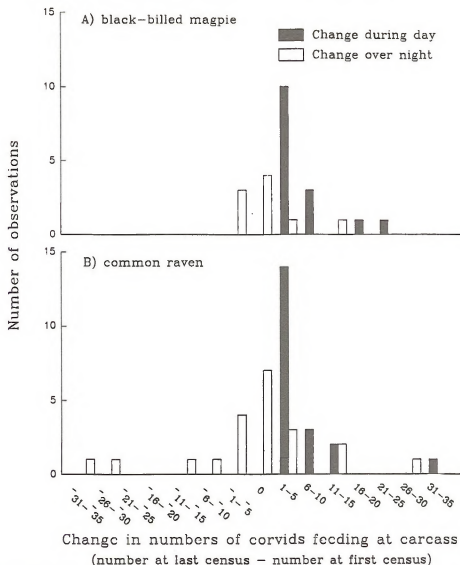


Fig. 4. The importance of local enhancement versus recruitment from the roost to the build-up of corvids at carcasses. Changes during the day equal the maximum number at the carcass during the day minus the number observed within the first 2 hrs of the day. Changes over a night equal the number observed within the first 2 hrs minus the maximum number observed the previous day. Zero indicates that numbers of corvids remained unchanged during the day or from 1 day to the next morning. Positive values indicate that numbers increased during the interval. Negative values indicate that numbers decreased. Changes during the day were calculated at 20 carcasses for ravens and 15 carcasses for magpies. Changes over a night were calculated at 11 carcasses over 21 nights for ravens and at 5 carcasses over 9 nights for magpies.

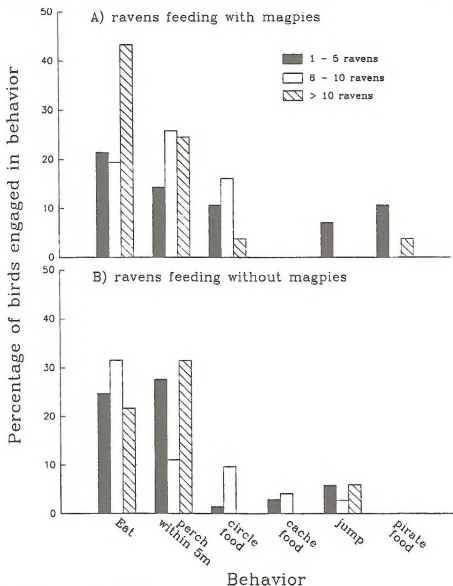


Fig. 5. Behaviors exhibited by ravens eating or preparing to eat. The behavior of each member of a group was recorded during a scan sample. "Perch within 5 m" indicates birds stationary within 5 m of the carcass. "Jump" indicates a fear response to new foods. Observations of pirating food were of ravens stealing food from magpies. Percentages were calculated based on the total number of individuals exhibiting any behavior (those in this figure and in Fig. 6) in each feeding group category (ravens feeding with magpies: 28 individuals in groups of 1-5 ravens, 31 in groups of 6-10, 53 in groups of > 10; ravens feeding without magpies: 69 in groups of 1-5 ravens, 73 in groups of 6-10 ravens and 51 in groups of >10 ravens).

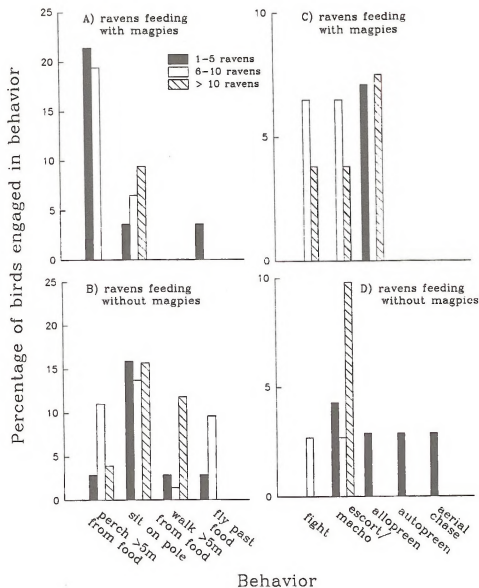


Fig. 6. Behaviors of ravens around the carcass. Behaviors exhibited by ravens away from the carcass (A, B) and behaviors associated with aggression and defense of the carcass (C, D) are plotted separately. Sample sizes are presented in Fig. 5.

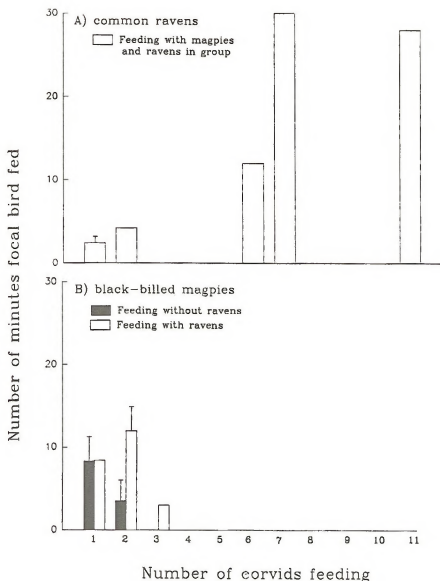


Fig. 7. The association between feeding group size and feeding rate. Feeding rates were calculated during a 30 min focal sample and therefore can reach a maximum of 30. Observations were insufficient to plot ravens feeding with and without magpies separately so all observations were lumped. The average (plus SE) of multiple observations per group size are plotted ($n = 4$ for ravens feeding alone, $n = 3$ for magpies feeding alone, $n = 2$ groups of 2 magpies without ravens, $n = 3$ groups of 2 magpies with ravens). All other observations are based on 1 sample of feeding by a bird in a given group size.

indicative of young subordinate birds and 2 had black mouths indicating that they were probably adults or exceptionally dominant immature birds (Heinrich and Marzluff 1992).

Association of Nestlings

We banded 29 and 31 nestlings from 11 and 13 nests respectively in 1991 and 1992. Fledglings were observed in family groups near their nests through mid July (up to 2 months after fledging). After this time, they began to disperse widely and were rarely seen again. One observation during the period of dispersal suggests that siblings passively separated by associating with other ravens foraging near their nesting territories. On 1 July 1992, 3 fledglings from Initial Point were observed within 2 km of their nest foraging with 4 other unmarked birds (2 of which may have been their parents). On 7 July they became more vagrant and began to separate; 2 were observed together without other ravens 7 km from their nest while the other fledgling was near the nest with a group of 8 other unmarked ravens. By 26 July, the Initial Point fledglings had dispersed (or possibly died) and other juveniles were seen moving through the area; 2 tagged juveniles were observed feeding in the alfalfa fields along Swan Falls Road with 30 other ravens (all unmarked). The marked juveniles were from Tadpole Butte East and Christmas Mountain Cinder Pit nesting areas (approximately 23 km away, straight line distance). This observation, and 2 others, suggests that siblings do not forage together beyond the time of dispersal. On 10 October 1991, 2 juveniles (1 from Swan Dam 3 Poles and 1 from either Thirst Draw or CSJ Downstream) were observed foraging together in a recently cut corn field with a

group of approximately 300 other ravens (all of which were unmarked). Similarly, on 9 July 1992, 2 tagged juveniles were observed on the slope of Christmas Mountain with 1 other unmarked bird. The tagged juveniles were not identified, but the color of their tags indicated that they were not from the same nest.

Ontogeny of Vocal Development

We captured 3 young ravens to study their vocal development in an aviary. Quantification of vocalizations is just beginning, but 1 result is noteworthy. Yells are very uncommon. Only 1 bird, the least dominant, gives yells and these are of low volume. Yelling appears to be triggered by hunger and the sight of other ravens eating; detailed tests are in progress.

■ DISCUSSION

Our observations begin to suggest how ravens find carcasses and assemble to forage upon them. Ravens usually search for food singly or in small groups, and typically 1 or 2 birds discover a new carcass. Discoverers are not usually territorial adults and rarely defend their finds. Group size increases over the course of the morning until a maximum of approximately 10 ravens feed upon the carrion. All members of the small feeding group rush in to feed and a dominant individual (not a pair) tries to defend, but gives up quickly as it becomes satiated. Local enhancement appears to be the primary mechanism of group formation. Ravens quickly cue in on other ravens as well as other scavengers and predators to locate new feeding opportunities. Recruitment from roosts is rare, possibly because most of the carcasses we looked at

were small and not located near traditional nesting territories; the 1 suspected case of recruitment from a roost occurred at a deer that was defended by a pair of adults. However, recruitment from roosts is unlikely to be common in the study area as most carrion items are jackrabbit carcasses and these are usually found along roadways outside of traditional nesting areas.

We can begin to assess alternative hypotheses for why ravens form groups at carcasses. Individuals are likely to benefit by increasing feeding rate as group size increases to 5 or 10. This is likely due to a reduction in neophobia, and is unlikely to result from an increased ability to overpower territory owners. In contrast, both factors favor group foraging in the boreal forest (Marzluff and Heinrich 1991). Reciprocity and indirect selection appear to be of lesser importance because tagged individuals do not associate with their siblings or form alliances. However, many more observations of foraging by tagged individuals will be needed to test these hypotheses.

Ravens in the SRBOPA appear to advertise the location of carcasses to a much lesser degree than ravens in the boreal forest. Foraging groups in the SRBOPA are relatively quiet; fights and chases are common and the typical "kaks" and "growls" associated with fighting are heard in the SRBOPA. However, submissive begs are rare, and, more importantly, 2 very loud and conspicuous calls that are common in the boreal forest, the "yell" and "trill", are very rare in the SRBOPA. Ravens from the SRBOPA are capable of yelling, but our aviary observations suggest that only very subordinate birds yell and that their yells are weak in volume.

■ PLANS FOR NEXT YEAR

We will continue to tag nestlings and monitor the exploitation of carcasses by corvids. We will increase our efforts to capture and tag territorial ravens and ravens discovering carcasses. The discovery and build-up of ravens at carcasses is adequately documented, however, more observations of behavior while ravens forage are needed to assess the costs and benefits of group foraging. The intriguing mutualistic information parasitism exhibited by raptors, corvids, and coyotes will be observed in greater detail in an effort to determine the costs and benefits to each participant.

■ ACKNOWLEDGMENTS

We would like to thank the many enthusiasts who spent hours watching dead animals do very little so that we might better understand how and why ravens form groups. Thank you Karen Clarke, Guyman Easdale, David Larson, Leslie LeRoux, Vincent Muehter, David Schuetze, Szabolcs Takacs, and Alice Whitelaw. We also thank Mary McFaden, Linda Schueck, Randy Townsend, and Mark Vekasy for keeping track of ravens while trapping for golden eagles. Bob Lehman, Laura Landon, Rick Olendorff and all the technicians working on the BLM/IDARNG research project were quick to alert us to potential nesting areas and sightings of marked ravens. Beth Telford and Marc Bechard provided recording equipment. Mike Kochert and Karen Steenhof helped in the permitting process, offered generous advice on the location of historical nesting areas, and provided literature and background information on ravens in the SRBOPA. This research was supported by Greenfalk Consultants.



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Habitat Relationships and Annual Variation in Breeding Passerine Birds on the Snake River Birds of Prey Area

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ANNUAL SUMMARY

We systematically surveyed breeding passerine abundances throughout the SRBOPA using 125 200-m radius circular point counts. Grassland species such as horned larks (*Eremophila alpestris*) and western meadowlarks (*Sturnella neglecta*) were most abundant, accounting for 68% and 22%, respectively, of the total number of individuals counted. Although over a third of our censuses were conducted in shrub-dominated habitat types, typical shrubland bird species such as sage (*Amphispiza belli*) and Brewer's sparrows (*Spizella breweri*), and sage thrashers (*Oreoscoptes montanus*) were much less common, representing only 10% of the total counted.

We observed statistically significant habitat associations of the principal grassland and shrubland bird species, both between and within major habitat types. Most of these associations were consistent with previous observations of these species in shrubsteppe ecosystems, although western meadowlarks achieved higher abundances in sagebrush shrublands than in grasslands. As in the previous year, sage sparrows, which are a characteristically abundant species in sagebrush-dominated habitat throughout the northern Great Basin, occurred at relatively low frequencies in our samples.

Although overall avian community composition changed relatively little between 1991 and 1992, horned larks, western meadowlarks, and Brewer's sparrows declined significantly. Whereas the decline in horned larks was spread over a variety of habitat types, declines in meadowlarks and sparrows were especially prominent in sagebrush habitats.

■ OBJECTIVES

1. To determine the abundance of breeding passerine birds in various shrubsteppe habitat types.
2. To examine annual variation in breeding passerine birds in different shrubsteppe habitat types.

■ INTRODUCTION

Passerine birds may be important predictors of habitat quality relative to land use practices in shrubsteppe ecosystems (Rotenberry and Knick 1991). They may also serve as significant sources of prey for raptorial birds (e.g., Clugston 1990). Thus, monitoring the distribution and abundance of passerines should be an important element of any long-term management plan on the Snake River Birds of Prey Area (SRBOPA).

We systematically surveyed breeding passerine abundances at sites throughout the SRBOPA during 1992, and repeated censuses at several sites sampled the previous year. Results of these surveys were used to address 2 basic questions: (1) what are the abundances of passerines in various shrubsteppe habitat types; and (2) is there significant annual variation in abundance in different habitat types? Answers to these questions will help evaluate differences among habitats in their ability to support prey for raptors.

■ METHODS

Study Area

The SRBOPA includes approximately 195,325 ha of Great Basin shrubsteppe in

southwestern Idaho. Once predominantly shrubland, about one-half of the shrubland in the SRBOPA has burned since 1975 (Kochert and Pellant 1986). Livestock grazing and military training are the primary land use activities.

Bird Surveys

During the May-June 1992 passerine breeding season, we counted breeding birds at 125 points scattered throughout the Integration Study Area (ISA) of the SRBOPA. At each point, counts were made of all birds [excluding ravens (*Corvus corax*) and falconiforms] seen or heard within a 200-m radius during a 3-min period (Rotenberry and Knick 1991). All censuses were conducted between 06:00 - 10:00 on mornings with little wind (0-12 km/hr) and no rain. Sixty-six of these points were surveyed in the same manner in both 1991 and 1992.

Vegetation Sampling

Habitat within a 200-m radius of each point was classified into a discrete vegetation type based on categories derived from the vegetation mapping effort of BLM/IDARNG research project Study 5 (Knick et al. 1991, this volume). If necessary, the final location of a sampling point was adjusted to maintain homogeneity of major habitat type within a 200-m radius.

Additionally, vegetation at 116 bird census sites was intensively sampled by Study 5 of the BLM/IDARNG research project during either 1991 ($n = 51$) or 1992 ($n = 65$) (Knick 1991, this volume). Percent cover of plant species was sampled by a point frame technique (Floyd and Anderson 1982) along transects scattered throughout a 100 x 400 m

sampling area centered on the census point. We also determined percent cover for litter and lichens. In this preliminary examination, we limited the vegetation variables used in our analysis to percent coverage of big sagebrush (*Artemisia tridentata*), budsage (*A. spinescens*), shadscale (*Atriplex confertifolia*), winterfat (*Ceratoides lanatum*), russian thistle (*Salsola iberica*), cheatgrass (*Bromus tectorum*), lichens, and litter.

Statistical Analysis

A datum was the number of individuals of a species counted within a 200-m radius of a sampling point (12.57 ha) during 3 min. Differences in species abundances among habitat types during 1992 were assessed using the Kruskal-Wallis test, whereas differences in species abundances between years were compared using a paired Wilcoxon signed rank test (Sokal and Rohlf 1981). These non-parametric tests were performed on untransformed counts using SAS (SAS Institute 1988).

We also examined the relationship of bird communities to habitat variables by canonical correspondence analysis (CCA) (CANOCO; ter Braak 1988). CCA is a multivariate direct gradient ordination of (avian) community variation relative to environmental variables (plant species coverages) (ter Braak 1986). In CCA, ordination axes of bird species data (representing variation in bird community composition) are constrained to be linear combinations of environmental variables. It is assumed that species have a unimodal response to underlying environmental gradients (ter Braak and Prentice 1988).

RESULTS

General Patterns

We conducted 125 point-count censuses between 4 May and 25 June, 1992. Vegetation data were available for 116 sites. Of these, 57 were in grassland habitat, 45 in shrub habitat, and 14 in disturbed areas dominated by russian thistle (Table 1). Sixty-eight sites (66 with vegetation data) were also censused in 1991. By far the most abundant birds were horned larks; they accounted for 68% of the total number of individuals seen ($n = 936$; Table 1). Horned larks were widely distributed throughout the study area, appearing on 110 of 125 point counts. Western meadowlarks were also common, accounting for 22% of the total number of individuals and occurring on over 60% of the counts (Table 1).

Typical shrubland bird species such as sage and Brewer's sparrows, and sage thrashers, were much less common, representing only 10% of the total counted (Table 1). Brown-headed cowbirds (*Molothrus ater*) and the charadriiform long-billed curlew (*Numenius americanus*) each made up less than 1% of the total counted.

Habitat Associations

Although both horned larks and meadowlarks were observed in all habitat types we censused, they nonetheless differed in their abundances between broad habitat categories. Horned larks were significantly more numerous in grasslands and disturbed areas than shrublands (Kruskal-Wallis test; $P < 0.001$), whereas meadowlarks were most numerous in shrublands and least common in

Table 1. Numbers of individuals seen on 3-min, 200-m radius point counts in different habitat types in the SRBOPA, April-June 1992. Entries are the average number of individuals counted and the number of counts on which they occurred (in parentheses). Values < 0.05 are not shown. "Total" is total number of individuals counted. "N" is number of censuses. Habitat types are more fully described in Knick et al (this volume).

	Shrublands			Grasslands				Disturbed		Grand Total (N = 125)
	Sagebrush (N = 27)	Other (N = 18)	Total (N= 45)	Native Grasslands (N = 8)	Cheatgrass (N = 36)	Sparse (N = 13)	Total (N = 57)	Russian Thistle (N = 14)	Total (N = 14)	
Grassland Species										
Horned Lark	2.2 (17)	4.2 (17)	135 (34)	5.9 (8)	7.4 (34)	5.8 (11)	387 (53)	5.0 (14)	70 (14)	636 (110)
Western meadowlark	3.6 (26)	0.3 (5)	101 (31)	1.6 (6)	1.3 (20)	2.2 (9)	86 (35)	0.7 (5)	10 (5)	204 (76)
Long-billed curlew	---	---	---	---	0.1 (3)	0.2 (1)	5 (4)	0.1 (1)	2 (1)	7 (5)
Shrubland Species										
Brewer's sparrow	0.8 (13)	0.2 (1)	26 (14)	0.4 (2)	---	0.4 (2)	9 (5)	0.1 (1)	2 (1)	38 (21)
Sage sparrow	0.5 (11)	0.5 (5)	22 (16)	0.4 (1)	0.1 (3)	0.2 (2)	8 (6)	---	---	33 (24)
Sage thrasher	0.2 (5)	0.1 (1)	7 (6)	---	0.1 (2)	0.1 (1)	3 (3)	---	---	10 (9)
Other										
Brown-headed cowbird	---	---	---	---	---	0.5 (2)	6 (2)	0.1 (1)	2 (1)	8 (3)

disturbed areas dominated by russian thistle (Kruskal-Wallis test; $P < 0.05$). Likewise, the typical shrubland species (Brewer's and sage sparrows) also varied among the 3 major habitat categories, and were significantly more abundant in shrublands (Kruskal-Wallis test; $P < 0.01$ for each species). Small sample sizes for the remaining species precluded detecting any differences in their distribution among habitat types, even at a coarse scale.

There were also statistically significant patterns of habitat association within the major categories of shrublands and grasslands. For example, both of the principal grassland species, horned larks and western meadowlarks, showed significant variation in abundance between the 2 shrubland types (Table 1; Kruskal-Wallis test; $P < 0.01$, $P < 0.001$, respectively). Horned larks reached significantly higher abundances in habitats dominated by shrubs other than sagebrush (principally shadscale or winterfat), whereas meadowlarks were more abundant in sagebrush shrublands. Of the shrubland species, only Brewer's Sparrows differed among habitat types, being significantly more abundant in sagebrush communities (Kruskal-Wallis test; $P < 0.01$). No species varied significantly among grassland types.

Relationships between bird species' abundances and the reduced set of vegetation variables determined by canonical correspondence analysis are summarized in Fig. 1. This "biplot" represents approximate values of the weighted averages of the bird species with respect to the vegetation variables (Jongman et al. 1987). The numerical axes serve to provide a framework

for displaying quantitative relationships among bird species and vegetation variables, but otherwise have no intrinsic meaning.

The first axis represents a bird-vegetation canonical correlation of 0.78, whereas the second represents a correlation of 0.65. Together they account for over 95% of the bird-vegetation association. However, there remains considerable unexplained variance, since only 37% of the total variation in species abundances is accounted for by these axes.

The most unexpected result was that sage sparrows did not cluster with the other typical shrubland species, Brewer's sparrows and sage thrashers, in a region of "habitat space" associated with sagebrush (Fig. 1). Instead, they lay more towards habitats associated with shadscale and budsage. This is consistent with data in Table 1 that show similar frequencies and abundances in sagebrush and other shrubland habitat types. It also appears that meadowlarks seem to respond to vegetation variation more like the typical shrubland species than like the other grassland species, horned larks. Again, this is consistent with data in Table 1.

Between-year Comparisons

Several species differed significantly between years, both within specific habitat types and over all types pooled (Table 2). Brewer's Sparrows were significantly more abundant throughout the SRBOPA as a whole in 1991 than 1992, as were Horned Larks and Western Meadowlarks. In Brewer's Sparrows, this was due to lower counts in shrublands, especially sagebrush-dominated habitat (Table 2),

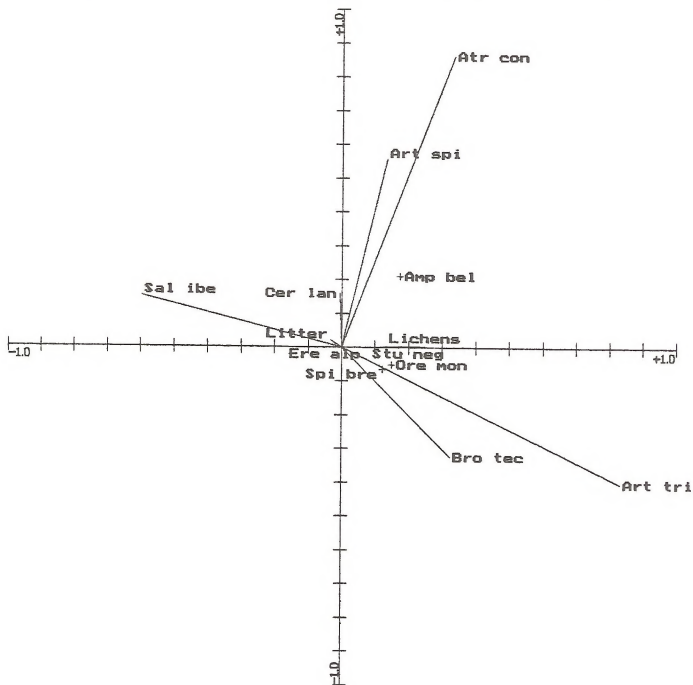


Fig. 1. Biplot of bird species (+) and vegetation (lines) scores for an ordination by canonical correspondence analysis. Codes are the first 3 letters of the genus and species

Table 2. Numbers of individuals seen on 3-min, 200-m radius point counts in different habitat types on the SRBOPA sampled in 1991 and 1992. Entries are the average number of individuals counted and the number of counts on which they occurred (in parentheses). Values < 0.05 are not shown. "N" is number of censuses. Habitat types are more fully described in Knick et al (this volume). Entries in bold denote statistically significant differences between years (paired Wilcoxon signed rank test, $P < 0.05$).

	Shrublands						Grasslands						Disturbed		Grand Total (N = 125)			
	Sagebrush (N = 27)		Other (N = 18)		Total (N= 45)		Native Grasslands (N = 8)		Cheatgrass (N = 36)		Sparse (N = 13)		Total (N = 57)				Russian Thistle (N = 14)	
Grassland Species																		
Horned Lark	4.6 (18)	5.5 (18)	7.8 (5)	6.0 (5)	5.2 (23)	5.6 (23)	11.2 (5)	8.2 (5)	6.9 (7)	7.1 (7)	9.5 (8)	6.5 (8)	9.0 (20)	7.2 (20)	7.8 (21)	5.6 (20)	7.3 (66)	6.0 (65)
Western meadowlark	3.0 (17)	1.8 (15)	1.4 (4)	—	2.7 (21)	1.4 (15)	0.2 (1)	0.2 (1)	2.1 (5)	0.7 (4)	1.0 (4)	0.9 (4)	1.2 (10)	0.7 (9)	1.6 (12)	0.9 (10)	1.7 (45)	1.1 (35)
Brewer's sparrow	1.6 (15)	0.5 (5)	0.4 (2)	—	1.3 (17)	0.4 (5)	—	—	—	—	0.3 (1)	—	0.1 (1)	—	0.5 (6)	0.1 (1)	0.7 (24)	0.2 (6)
Sage sparrow	0.6 (6)	0.3 (5)	—	0.8 (3)	0.4 (6)	0.4 (8)	—	—	—	—	—	—	—	—	—	—	0.2 (6)	0.2 (9)
Sage thrasher	0.1 (2)	0.1 (2)	—	0.2 (1)	0.1 (2)	0.1 (3)	—	—	—	—	—	—	—	—	—	0.1 (2)	0.1 (2)	0.1 (5)

where these sparrows otherwise achieve their highest abundances (Table 1). Likewise, counts of meadowlarks decreased on sagebrush sites, as well as on russian thistle-dominated points (Table 2). For horned larks, lower counts in 1992 were spread across more habitat types, with no single type varying significantly (Table 2). In general, within-habitat sample sizes were too low for most species to detect all but the grossest changes in abundance between years.

■ DISCUSSION

SRBOPA habitats differed at both coarse and fine scales of classification in their ability to support different species (Table 1). In general, the patterns of distributions of passerine species across habitat types were broadly consistent with previous observations in shrubsteppe ecosystems (Wiens and Rotenberry 1981, Smith et al. 1984). However, sage sparrows, which are otherwise a characteristically abundant species in sagebrush-dominated habitat throughout the northern Great Basin, again occurred at relatively low frequencies in our samples, being present on only 11 of 27 counts in native sagebrush habitats and only 16 of 45 counts in shrublands generally (Table 1). We have speculated previously (Rotenberry and Knick 1991) that this may reflect landscape-level processes, principally the fragmentation of the original large tracts of native sagebrush habitats that historically existed throughout the SRBOPA (Yensen 1980) due to disturbance, particularly fire, grazing, and introduced exotic annual vegetation.

Significant between-year variation in point count totals (Table 2) may have several

sources in addition to changes in the number of individuals of a species actually present throughout the sampling area. For example, we used a different set of observers in 1992 compared to 1991, with only 1 individual participating in both years. Inter-observer variation can produce systematic differences among sets of censuses if observers exhibit any biases in counting and are themselves distributed systematically among counts being compared (i.e., between years). This is unlikely to be a factor in our interpretation of between-habitat differences, however, as observers were randomly assigned to points across all habitat types.

We may also appear to detect significant differences in abundance, even in the absence of area-wide population changes, if individuals change their spatial distribution relative to our sampling points. This is especially likely if species abundance in a particular patch or habitat type is already low, or if territories are only loosely packed. This phenomenon is the "checkerboard effect," and has been explicitly described for shrubsteppe bird communities, albeit at a somewhat larger spatial scale (Rotenberry and Wiens 1980, Wiens 1981). This particular phenomenon can be examined (and to some degree "mitigated") by increasing the density of points sampled throughout the region of interest. We are also trying to develop spatially-explicit statistical approaches to measure the degree of this effect (e.g., Milne 1988, Palmer 1988).

The mitigation of potential systematic differences in observers affecting annual differences in species counts can be addressed in several ways. First, the same individuals can be used in all years. Although difficult to implement, this produces the best results. Second, numerous

individuals can be used in each year, so that a variety of counting biases are present in each year. This leads to a more accurate estimate of a mean value for each species, but at the cost of increased variance (and, hence, reduced statistical power) about that mean. Third, all observers can undergo rigorous and consistent pre-census training, followed by testing prior to and throughout the census period. Properly applied, this technique can reduce inter-individual variation to nonsignificance (Kepler and Scott 1981).

In conclusion, we strongly recommend continuing passerine censuses throughout SRBOPA. An enlarged database will allow us to address several important questions about habitat associations of shrubsteppe birds. Because we will have multiple samples within the same general habitat type (e.g., big sagebrush, exotic annual grassland, or salbush), we can assess intra-habitat (i.e., spatial) variation in abundance. As our Geographical Information System-based vegetation map becomes increasingly accurate (Knick et al. 1991, this volume), we will be able to address questions relating species distribution and abundances with important landscape features (e.g., Pulliam 1988).

We have also begun to characterize habitat quantitatively at a relatively fine scale, as each of the existing BLM/IDARNG Study 5 vegetation transects is sampled intensively for plant species composition, coverage, and physical structure (Knick 1991). These measurements can be coupled with bird numbers to generate habitat correlations of species' abundances. Comparison of these correlations with those observed elsewhere (e.g., central Oregon; Wiens and Rotenberry 1981, Rotenberry 1986) will permit

assessment of the regional consistency of a species' habitat selection patterns. These correlations may also be useful in predicting avian responses to changes in vegetation that might occur under different management options.

Finally, these observations can provide the basis for long-term monitoring of passerine populations on SRBOPA. Continued monitoring can provide information on annual variation in species abundances within and between general habitat types, and can be used to detect temporal trends in regional population numbers. Such trends may reflect large-scale habitat loss in either breeding or wintering areas, or changes in vegetation quality and composition due to management or climate change.

" RECOMMENDED PLANS FOR NEXT YEAR

1. Funding should be secured to continue both general passerine surveys as well as evaluation of the effects of habitat fragmentation.
2. A subset of sites sampled in 1992 should be selected for resampling in 1993, as should some that were sampled in 1991, with the goal of incorporating these locations into a network of sites for long-term passerine monitoring.
3. Additional new sites should be selected in 1993 using generally the same criteria as in 1991-92, which will permit the addition of new sites to the monitoring network. New sites should also be selected within the SRBOPA south of the Snake River to increase the range of habitats sampled for bird distributions.

▪ ACKNOWLEDGMENTS

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Energetics, Survival, and Reproductive Endocrinology of Hibernating Townsend's Ground Squirrels

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ANNUAL SUMMARY

*Experiments are underway that will aid our understanding of the role of hibernaculum temperature on the energy budget and reproductive endocrinology of Townsend's ground squirrels (*Spermophilus townsendii*). We present results of preliminary experiments performed on young-of-the-year males and females which indicate that males lose fat faster than females, but which show no clear trends in effects of hibernaculum temperature on testosterone and estrogen levels.*

OBJECTIVES

1. Determine rate of survival and cause of death for hibernating Townsend's ground squirrels in the Snake River Birds of Prey Area.
2. Determine which physical and biological factors influence overwinter survival of Townsend's ground squirrels.
3. Determine the extent to which overwinter mortality affects observed

abundance and distribution of Townsend's ground squirrels.

4. Determine how choice of hibernaculum influences influences reproductive readiness and energy usage.

■ INTRODUCTION

Townsend's Ground Squirrels spend approximately 6 months per year in estivation/hibernation, entering their burrows in June-July, and not emerging until January-February. The rate of survival during this period is low: Smith and Johnson (1985) estimated it to be 21-38% (although some of the loss may be due to unobserved dispersal). Therefore, variation in overwinter survival has the potential to significantly influence populations of Townsend's ground squirrels.

The determinants of overwinter survival have yet to be elucidated, but it seems likely that because the squirrel must rely on fat stores to finance its 6 months underground, a shortfall in those stores may be an important cause of overwinter mortality (Murie and Boag 1984). Studies of other species of ground squirrel (e.g., Pengelley and Fisher 1961, Twente and Twente 1967, Morrison and Galster 1975, Young 1988) indicate that individual squirrels allow their body temperature to drop to the temperature of their hibernaculum or to 2-3 C above freezing, whichever is highest. Every 1 to 3 weeks, the squirrels arouse, raising their body temperature to the normal, euthermic level for a period of approximately 1 day. Costs of maintenance, which are reduced by approximately 95% compared to standard euthermia, are lower at lower burrow temperature.

A shortfall in fat reserves could be due to 1 of 2 causes. First, too little fat may have been accumulated prior to immersion. Second, maintenance and thermoregulatory needs may have been excessive, perhaps due to the thermal environment within the hibernaculum.

Reproductive competence upon emergence from hibernation may be affected by hibernaculum temperature as well. Barnes et al. (1987) found that in golden-mantled ground squirrels (*Spermophilus lateralis*), *in vitro* stimulation of testicular tissue by luteinizing hormone (LH) results in testosterone secretion at temperature of 32 C, but at 5 C. Because testosterone production is dependent on temperature, production should be higher in squirrels in warmer hibernacula, because the temperature during hibernation is higher and because arousal frequency (and therefore total time spent in euthermia) is higher.

The physical environment and the behavior of the squirrel should both be important in determining the thermal environment of the hibernaculum. Important aspects of the physical environment include factors such as slope, aspect, and vegetation cover. Vegetation cover is particularly interesting since it affects both incident solar radiation (Moen 1968, Daubenmire 1972) and convective heat exchange (Porter et al. 1973, Nobel and Geller 1987). Vegetation cover is often severely affected by the activities of humans (e.g., grazing [Yensen 1982] and fires [Yensen 1981, Kochert and Pellant 1986]), and therefore may be the primary factor connecting human impacts with hibernation energetics and survival of Townsend's ground squirrels. Within the conditions available, the exact placement of the hibernaculum will affect its temperature characteristics.

▪ METHODS

Laboratory Experiment: Nineteen young-of-the-year and 1 adult *S. townsendii* were captured at the N edge of the Snake River Birds of Prey Area, near Swan Falls Road. Body fat content was determined using a EMSCAN body composition analyzer, and 10 of the squirrels were implanted with temperature sensitive radiotransmitters. Following 2 weeks of acclimation to laboratory conditions, 200 μ L of blood was removed from the suborbital sinus of each squirrel to later be analyzed by radioimmunoassay to give baseline testosterone or estrogen levels. Squirrels were then housed at 17 C until mid-October, when half were moved to a cabinet at 21 C and the other half to a cabinet at 17 C. Temperatures were gradually lowered to 7 C and 13 C, roughly mimicking changes measured at 1-m depth at our field site. The difference between cabinet temperatures is a slight exaggeration of the 2 C difference recorded between the 1-m temperature under a shrub cover and the 1-m temperature in an open habitat. Body temperature was recorded daily to give an indication of the frequency with which arousal occurs. In early January, at approximately the time that

arousal would occur, and at 2 dates 3 and 6 weeks later, another 200 μ L of blood will be taken from each squirrel and analyzed via radioimmunoassay. Body composition was again measured.

▪ RESULTS

Fig. 1 shows the regular occurrence of arousal bouts approximately every 5 days. As expected, there was a dramatic loss of body mass during hibernation, but there was not a significant effect of temperature. (Figs. 2, 3). There was, however, a significant difference between the sexes: males lost more weight than females (ANOVA). Body composition showed similar results, with males losing more body fat than females (ANOVA; Fig. 4).

No effects on testosterone or estrogen production were detected (Repeated measures ANOVA; Figs. 5, 6, 7, and 8), a result that is perhaps not surprising given that yearling males do not breed in this species.



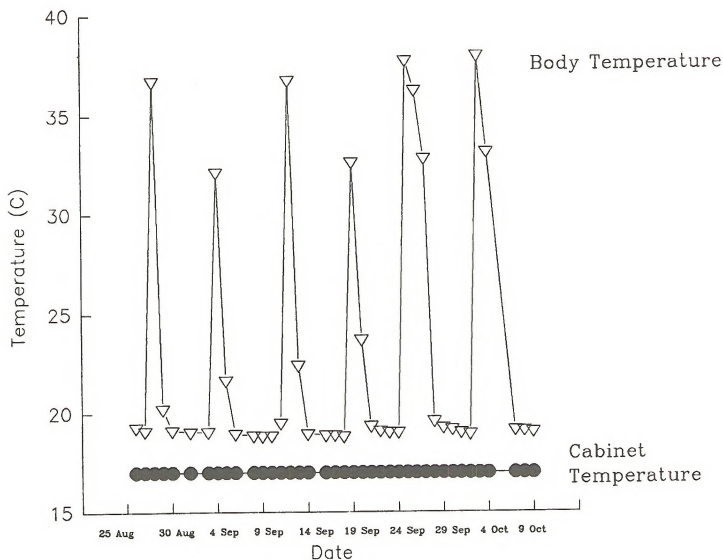


Fig. 1. Example of daily recordings of body temperature from a squirrel held at approx. 17 C, showing regular arousal bouts.

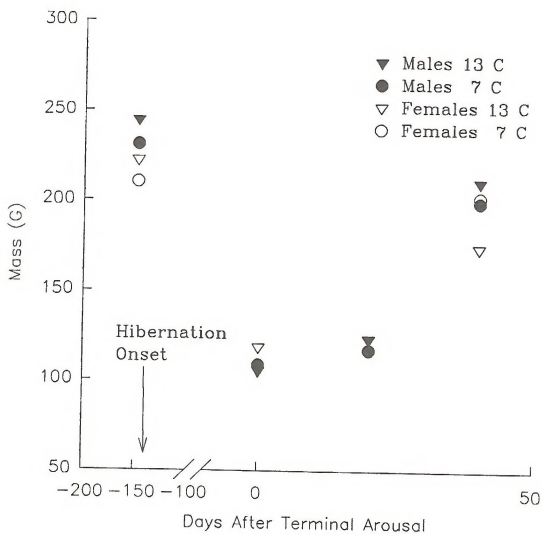


Fig. 2. Change in mass during and after hibernation. For females at 7 C, N = 4; for female at 13 C, N = 7; for males at 7 C, N = 5; and for males at 13 C, N = 3.

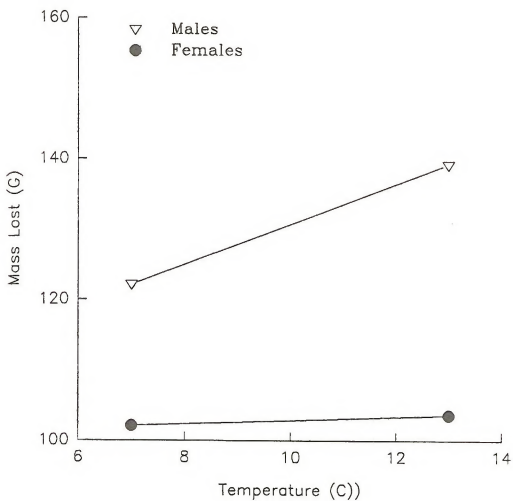


Fig. 3. Effects of temperature and sex on body mass lost.

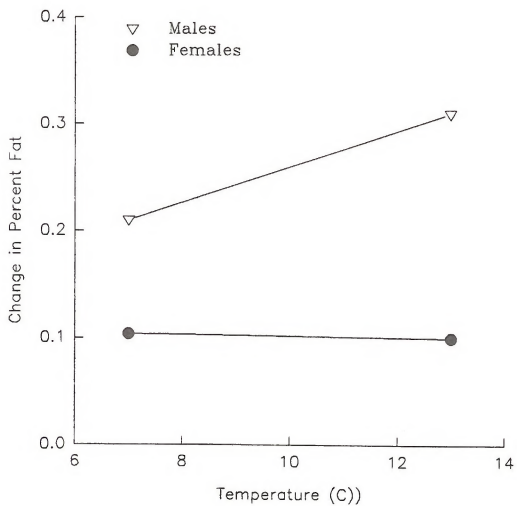


Fig. 4. Effects of temperature and sex on %-change in body fat.

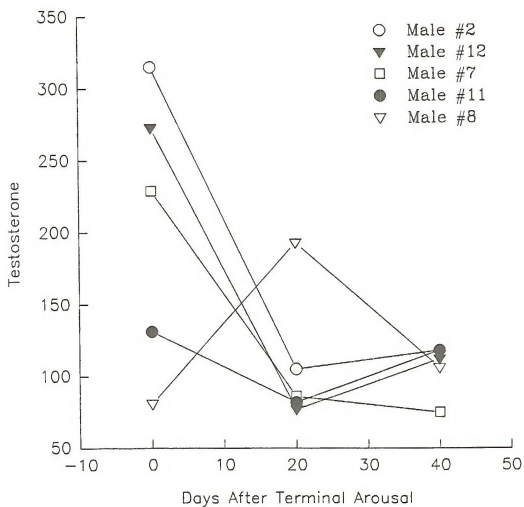


Fig. 5. Testosterone levels (in picograms per mL of blood) of male squirrels held at 7 C.

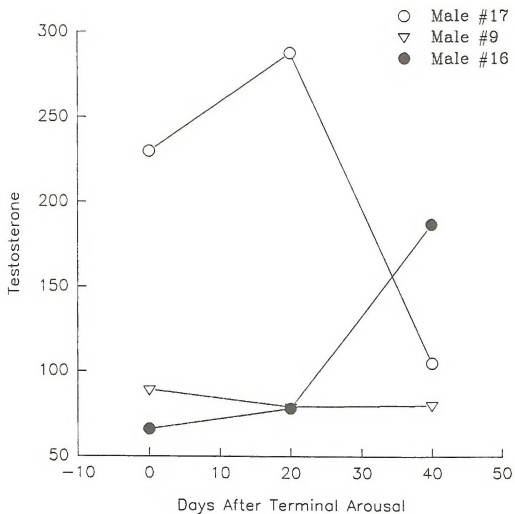


Fig. 6. Testosterone levels (in picograms per ml of blood) of male squirrels held at 13 C.

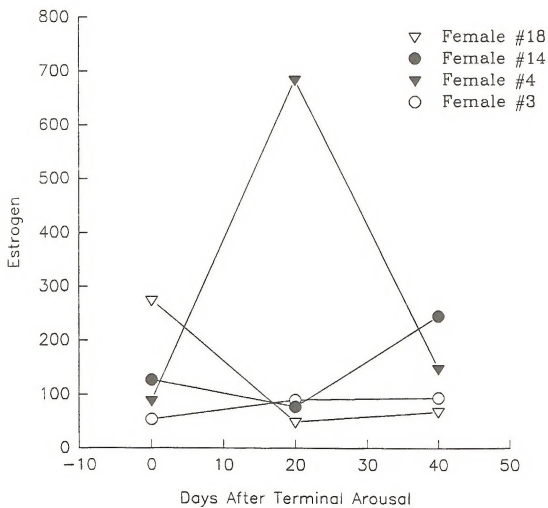


Fig. 7. Estrogen levels (in picograms per ml of blood) of female squirrels held at 7 C.

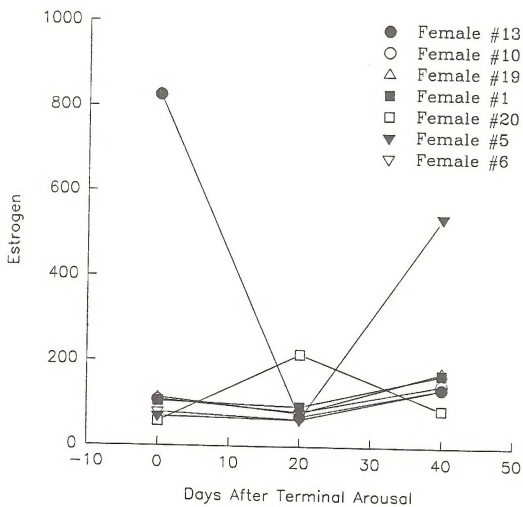


Fig. 8. Estrogen levels (in picograms per ml of blood) of female squirrels held at 13 C.

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Feasibility of Using Radio-telemetry to Study Dispersal Movements of Townsend's Ground Squirrels on the Snake River Birds of Prey Area (SRBOPA)

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ANNUAL SUMMARY

*Four Townsend's ground squirrels (*Spermophilus townsendii*) (2 adult females, 1 each juvenile male and female) were fitted with radio collars. Three of these squirrels (2 adults and 1 juvenile male) were radio tracked from 4 June to 29 June. Squirrels generally accepted the collars, and did not appear bothered by properly fitted collars. It was not difficult to detect transmitter signals from at least 400 m away, even when the squirrel was underground, when there was a clear line of sight. It was often possible to determine its exact location underground. None of the instrumented squirrels left the study area. Use of many burrows by the same squirrels indicates that counts of "active" holes during this period were probably a poor index of squirrel activity; these 3 squirrels alone made a number of holes appear "active". I conclude from this pilot study that radio-telemetry can be used to monitor squirrel movements, and may have a number of uses aside from those related to dispersal.*

▪ OBJECTIVES

1. Determine if dispersal movements of juvenile Townsend's ground squirrels can be detected with appropriate radio-telemetry equipment.
2. Determine the effects, if any, of 2 types of collaring devices on the behavior of collared juvenile Townsend's ground squirrels.

▪ METHODS

On 1 June 1992 I received 5 radio collars from Advanced Telemetry Systems, Inc. (ATS), and I rented a receiver. The collars weighed about 6.5 g and operated on frequencies in the 149-Mhz range. On 3 and 4 June, under normal trapping protocol for Study 4, I put 4 of these collars on ground squirrels trapped on Study 4 Site 8B. Two of these were placed on adult females, 1 on

a juvenile male, and 1 on a juvenile female. I was unable to carry out my plan to collar only juvenile males because due to drought conditions, not enough of these were captured of sufficient weight. (I set a minimum of 130 g so that collars would be no more than 5% of body weight.) One of the collared squirrels (the juvenile female) slipped her collar within hours, but I was able to retrieve it. She had shown an aversion to the collar which the others had not, and the looser setting she accepted was apparently too loose to remain on. If I had had equipment to punch a hole intermediate between the ones provided by ATS, I'm sure I could have found a setting that she would have accepted and not lost.

I attempted to place the remaining 2 collars on ground squirrels at 2 other study sites, but no animals were trapped of sufficient size. By early June, most adults had entered hibernation, and juveniles were too small. I attribute both to the drought conditions.

I fixed locations of the 3 collared squirrels 2 times per day on 4 and 5 June, once daily from 7 June - 11 June and once a day on 10 days during the time period: 13 June - 29 June. Locations were determined by tracking each squirrel to a particular burrow. It was often possible to determine its exact location underground, and tell whether that burrow had more than 1 entrance. A few times squirrels were still active above ground while I was attempting locations; if they did not immerse into burrows and remain there for at least 15 min, I did not take that location. I visited the site at different times during the day to determine the best time to locate squirrels; I found they were not active in the middle of the day, so that was the best time to fix their locations without influencing movements. It was not difficult to detect transmitter signals

from at least 400 m away, even when the squirrel was underground, when there was a clear line of sight. Some difficulty was encountered due to slight undulations in topography, and 1 squirrel which primarily used a rocky area was often hard to detect unless I was within 100 m or so. However, once I had developed a good search technique it was relatively easy to locate squirrels.

■ RESULTS AND DISCUSSION

None of the 3 squirrels I radio-collared left the study area. In fact, 1 that was caught on an assessment line subsequently moved to within the grid trapping area and remained there. Another squirrel was occasionally tracked to burrows off the grid, but most locations were within the 2.25-ha trapping grid for that site. All 3 squirrels estivated within the trapping grid area. Contrary to normal procedure, the juvenile male immersed earlier (6 June) than either of the adult females (9 and 10 June). Immersion (or possible mortality) of the juvenile at this time was not unusual for this year based on Study 4 trapping records; it was more unusual for the 2 adult females to remain active as long as they did. It is possible they did so as long as we trapped the area and bait was available; they immersed shortly after trapping was suspended for the year on that site. The exact locations of estivating squirrels were permanently marked and measured for possible retrieval of radio collars in 1993.

I have not yet fully analyzed actual movement data, nor do I consider it high priority with only 3 animals collared. I marked all burrows and measured the distance and bearing to nearest pole so locations could be plotted. This has been

done, but no further analysis has been attempted at this time. All 3 squirrels used a number of burrows that could not have been connected. In fact, until estivation began I never found the same squirrel in the same burrow twice. Visual observations indicated that these were nearly the only squirrels active during this period. Their use of a number of different burrows (they never overlapped) indicates that counts of "active" holes during this period were probably a poor index of squirrel activity; these 3 squirrels alone made a number of holes appear active.

I conclude from this very modest pilot that radio-telemetry can be used to monitor squirrel movements, and may have a number of uses aside from those related to dispersal, which remains my main interest. The ability to trace a squirrel to its exact location underground was an unexpected bonus. I was also encouraged by the squirrels' general acceptance of the collars. Observations of collared squirrels indicated that they were not at all bothered by them when properly fitted. A slightly different type of collar may need to be used in a more normal year, or when collars are left on for longer periods, as it would need to expand as squirrels added weight prior to hibernation. This was not a factor in this drought year.

Because of the drought, I would hesitate to draw any conclusions whatsoever regarding movements of squirrels from this study. I suspect that squirrel behavior was highly altered due to the stress they were under. The site I used was virtually barren of any food source, and this must have severely affected the ground squirrels. I think that radio-telemetry is an under-utilized technique (on ground squirrels) that merits further investigation.

■ PLANS FOR NEXT YEAR

No telemetry work is proposed for 1993; however, such a project may be proposed for 1994.

■ ACKNOWLEDGMENTS

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Fire Scar Mapping Using Landsat Multispectral Scanner Imagery

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ANNUAL SUMMARY

Ability of Landsat Multispectral Scanner (MSS) satellite imagery to map burned areas was evaluated. If possible, then fire scars could be mapped for periods of image availability for areas lacking fire maps documented from other sources. An unsupervised classification procedure was used for 3 MSS images of the Snake River Birds of Prey Area, and fire scars were delineated from grassland cover classes. When compared to U.S. Bureau of Land Management fire maps, some fire scars were accurately mapped by using satellite imagery. However, not all recent burns were detected, possibly because these burns occurred in grassland rather than shrub dominated habitats. Future evaluation of satellite potential for mapping fire scars should examine a supervised classification procedure as well as other data sources, such as infra-red photography or Thematic Mapper satellite imagery.

■ OBJECTIVE

To determine the feasibility of using Landsat Multispectral Scanner satellite imagery to map fire scars in the Snake River Birds of Prey Area.

■ INTRODUCTION

This report documents the Snake River Birds of Prey Area (SRBOPA) fire scar

mapping project. The purpose of this project was to evaluate the potential of mapping historical fire scars using image processing of Landsat Multispectral Scanner data.

Landsat MSS data was chosen because it offers continuous coverage of the SRBOPA back to 1972 and thus offers a good source of data for historical fire scar mapping. Other alternative sources of satellite data are the Landsat Thematic Mapper (TM), available back to July 1982, and SPOT data, available back to February 1986. Neither of these sources of data is useful in respect to the BLM current goal of mapping fire scars

back to the early 1970's. For detailed descriptions of Landsat TM and MSS and SPOT data see Lillesand and Kiefer (1987).

The other alternative for mapping fire scars is historical aerial photography, but its usefulness is limited by its availability. In contrast, Landsat MSS data offer continuous coverage. Data are available every 18 days from Landsats 1, 2, and 3, and every 16 days from Landsats 4 and 5. And because Landsat MSS data is available in digital form it is readily geocorrected to map projections and analyzed using image processing and GIS software. The main advantage that aerial photography has over Landsat MSS data is the resolution--smaller objects are identifiable--but for mapping fire scars as required for this project the Landsat MSS pixel size of 57 by 57 m is adequate.

For the purpose of this project, fire scars are defined as any areas that have been altered by fire in the past. This includes areas of relatively recent known fire scars that still have visible patterns or remnants of fire and also areas that were probably affected by fire but have since recovered and regrown to grasslands.

■ LITERATURE REVIEW

Reviews of remote sensing applications in arid environments were presented by Tueller (1987) and Smith et al. (1990). The main limitation for mapping vegetation discussed in these articles is that sparse vegetation cover in arid regions causes the spectral response of an area to be largely dependent on characteristics of the soil surface. Tueller (1987) summarized the areas of research that

need to be conducted to help improve remote sensing mapping efforts in arid areas. Neither of these reviews discussed fire scar mapping because there has been little research for this application in arid rangeland environments (Tueller, Univ. Nevada, Reno. pers. commun.).

SeEVERS et al. (1973) published the first article dealing with this subject. They discussed how 1 recent known fire scar in the Nebraska sandhills was visually interpreted and mapped using a Landsat MSS infrared (IR) image. Acreage figures mapped using Landsat compared favorably with field estimates.

Milne (1986) and Richards and Milne (1983) discussed use of Landsat MSS data for mapping fire scars and monitoring the regrowth of vegetation in bushland areas of Australia. Milne (1986) presented several change detection techniques and stressed the importance of starting any change detection study with an accurate pre-fire vegetation map. Richards and Milne (1983) focused on a change detection technique using the principal component transformation on a pre- and post-burn multitemporal MSS scene. Areas of change, like a fire scar, are enhanced, while stable areas are suppressed. Both of these studies were basic short-term research projects and the techniques used may not be successful or practical to use in a project with long-term goals of mapping fire scars back to the early 1970's. The most useful idea presented in these papers was the suggestion to use the Infrared/Red (IR/RED) band ratio, not to map fire scars, but to use as an indicator of relative burn severity, for areas that are already mapped as fire scars (Milne 1986).

Everitt and Nixon (1985) discussed how video technology can be used as a remote sensing tool for rangeland management. The video can complement or replace satellite imagery for certain applications. One of the applications mentioned is the visual identification of a known fire scar using an IR image. Some advantages of video compared to satellite data and aerial photography are: 1) Video systems can be designed for a specific application. A standard color video camera may be adequate for some applications but a multispectral high-resolution system could be developed for an application that requires more detailed data. 2) The video can be monitored as data is collected so sites can be flown again if they are missed and areas can be zoomed in on for more detail. 3) Comments can be recorded while in flight to accompany the video recording. It is probably not practical to use video as the sole source of data for research in a study area as large as the SRBOPA. This would depend on the specifications of current video technology. But video may be useful to identify and map recent fire scars or to monitor fires in progress.

■ METHODS

ERDAS was the image processing software used to geocorrect the images, and to generate spatial and spectral enhancements. ERDAS raster GIS overlay programs were used to produce change maps and to compare the fire scar maps produced using Landsat MSS data with the U.S. Bureau of Land Management (BLM) fire scar maps for accuracy assessment. Spectral Software Associates software (Morse et al. 1990) was used to cluster and classify the images and ARC/INFO was used to produce plots. For details of remote sensing principles refer to Lillesand and Kiefer (1987). For discussions and illustrated examples of image processing procedures refer to Jensen (1986).

Data Description

Three Landsat MSS scenes were chosen for analysis (Table 1). These were the most recent scenes with a maximum 10% cloud cover in a spring-fall-spring sequence. This sequence was desirable to determine if fire scars of 1 season could be mapped using scenes from before and after 1 fire season.

Table 1. Landsat-5 MSS scenes used to map fire scars in the Snake River Birds of Prey Area.

Path/Row	Date	Scene-ID
41/30	20 Apr 87	85114517490X0
41/30	27 Sep 87	85130517530X0
41/30	24 May 88	85154517562X0

Geocorrection Process

The Landsat MSS scenes were geocorrected to the Universal Transverse Mercator (UTM) projection using 15 ground control points (GCPs). Most GCPs were road intersections. The GCP UTM coordinates were taken from 1:24,000 USGS quads and used to generate a 2nd order polynomial transformation. Total root mean square errors were 57.00, 42.75, and 45.03 m for the 20 April 1987, 27 September 1987, and 24 May 1988 scenes, respectively. A 57 by 57 m pixel-size and bilinear interpolation were selected for resampling. Output images were 1681 columns by 1229 lines and included a 500-m buffer around the SRBOPA. A detailed example of geocorrection procedures is presented in Jensen (1986).

Spatial Enhancements

Spatial filters are used to enhance images by increasing the contrast between a central pixel and the surrounding pixels. Edge filters are a form of spatial filter used to delineate boundaries between features. Spatial and edge filters of different degrees and sizes (3 X 3, 5 X 5, and 7 X 7 pixels) were evaluated to determine if they could help distinguish fire scars. For detailed descriptions and illustrations of the effects of filters see Jensen (1986).

Spectral Enhancements

Several spectral enhancements were evaluated. These included the IR/RED and (IR-RED/IR+RED) vegetation indexes (VI). These VIs are used as indicators of the relative amount of vegetation cover or biomass (Jensen 1986). These were applied because areas affected by fire should have

lower vegetation cover and biomass and lower VI values than surrounding unburned areas, thus the VI images should help distinguish fire scars.

Principal component analysis (PCA) is a statistical procedure that has been commonly used in remote sensing to reduce the dimensionality of Landsat MSS data from 4 to 2 dimensions (Jensen 1986). PCA can also produce images that are more readily interpretable than raw images, but the results are scene dependent and thus are slightly unpredictable. PCA was applied to all the images to determine if transformed images might make fire scars more distinguishable.

The Tasseled-Cap (TC) transformation was developed empirically (Kauth and Thomas 1976). The TC is called Vegetation Components in Lillesand and Kiefer (1987) because it has similar properties to PCA. But in contrast to PCA the TC produces data that is directly related to biophysical scene characteristics. The first TC component, Brightness, is related to soil reflectance and the second TC component, Greenness, is related to the amount of vegetation cover and biomass. All 3 Landsat MSS scenes were corrected to a solar zenith angle of 39° before applying the TC transformation (Kauth et al. 1979). The TC Brightness and Greenness false color composite (FCC) made known fire scars slightly more visible than on the raw data FCC so it was used for further visual and digital analysis.

Classification

The original plan was to select the best enhanced images and to visually identify and screen digitize fire scars. It was readily apparent to BLM personnel, based on their knowledge of the SRBOPA, that many areas

of fire scar that had recovered and were now grassland would be missed with this method so it was decided to conduct a land cover classification of each image; primarily to map grassland so these areas could be mapped as fires scars throughout the SRBOPA. Each of the 3 scenes were processed independently so they could be compared and evaluated to help determine if a spring or fall scene would be best to map fire scars.

The 2 main approaches to classification are supervised and unsupervised (Jensen 1986; Lillesand and Kiefer 1987). An unsupervised approach was used in this project due to the time and budget constraints of the project. Because conducting a land cover classification was not in the original plans, it would have been prohibitively expensive to develop and evaluate the training data required for a supervised classification.

The unsupervised classification approach involved the following steps: 1) Agricultural and wetland areas were masked out of the images to limit the image processing and analysis to areas that might contain fire scars. 2) Each scene was clustered and classified into 100 spectral classes using an iterative converging algorithm (Forgy 1965). The number of spectral classes chosen was a judgement based on previous experience in classification of Landsat MSS data. 3) The spectral classes were grouped into 7 cover classes based on known and estimated cover as determined by the BLM. The classes were water, dense sage, 3 mixed vegetation classes, low density grass, and high density grass.

The next step was to screen digitize areas of fire scar or potential fire scar that could be distinguished with visual analysis. These

were areas with characteristic fire scar patterns; either oval shapes and/or spectral responses very different from surrounding land. Fire scars were screen digitized with a small buffer of 2-3 pixels and then rasterized into a GIS file. A matrix was developed that included all fire scars that were screen digitized and the land cover classes. Land cover classes were grouped into fire scar and non-scar categories individually for each fire scar. A matrix overlay combined the 2 files to map the fire scars more precisely than would have been possible with only screen digitizing. This process is a modification of the post-classification sorting stratification technique described by Hutchinson (1982).

The final steps included: 1) Eliminating roads from fire scar areas. The ARC BTRAN (roads) coverage was rasterized using POLYGRID and overlaid on the final fire scar ERDAS GIS files to subtract out a 1-pixel-wide area for roads. 2) Deleting areas of fire scar smaller than 2 ha based on a practical size limitation determined by the BLM. The CLUMP and SIEVE programs in ERDAS were used to first identify and then eliminate contiguous groups of pixels, classified as fire scar, smaller than 6 pixels (approximately 2 ha) in size.

Fire Scar Mapping Accuracy

Two composite BLM fire scar maps were produced for the accuracy assessment so areas of fire scar that burned in more than 1 year would only be assessed for the most recent year. The ARC POLYGRID program rasterized all 8 of the BLM fire scar maps for the 1980 to 1987 fire years. These were overlaid using the ERDAS GIS modeling program to produce 2 composite maps. The 1980 to 1986 maps were combined to assess the accuracy of the 20 April 1987 Landsat

fire scar map and the 1980 to 1987 maps were combined to assess the 27 September 1987 and 24 May 1988 Landsat fire scar maps.

Accuracy was assessed visually by displaying a Landsat fire scar map in the image plane and a BLM composite fire scar map in the graphics plane. This allowed BLM fire scars from individual years to be highlighted while simultaneously being able to view the Landsat fire scar maps. Fire scars were recorded as being mapped accurately or missed based on the area and shape of the fire scar in respect to the BLM mapped fire scars. The size of fire scars was not taken into account so relatively small fire scars affect the results the same as larger fire scars. Using this method, only errors of omission are assessed. To assess errors of commission would have required fieldwork in areas mapped as fire scar using Landsat MSS that were not mapped as fire scar on the BLM maps.

Map Production

Maps were produced using ARCPLOT software and plotted on an electrostatic plotter. This required that all ERDAS GIS files be converted to ARC coverages. All ERDAS files were kept 8-bit as required by the current PC version of the ARC raster-to-vector conversion program (GRIDPOLY). This was done by assigning class codes of 16 to fire scars and 1 to areas of non-scar. The parameters required by GRIDPOLY were the lower left UTM Zone 11 coordinates (X:532040, Y:4740839), pixel-size (57 by 57 m), and the size of the files (1,681 columns by 1,229 lines).

Two software limitations in the PC version of ARC need to be discussed. 1) The maximum number of arcs allowed in a

polygon is 5,000. If the GRIDPOLY program reaches this limit as it is creating a coverage it discontinues processing. 2) The maximum number of points per polygon in an electrostatic plotfile is 2,500. The ARCPLOT software will still produce a plotfile if this limit is exceeded but the polygon will not shade in on the plot. To circumvent these software limitations, vectors were edited into the ERDAS GIS files prior to conversion. These vectors split larger polygons into smaller polygons thus reducing the possibility of reaching either of the software limitations. The pixels in the edited vectors were recoded using an offset of 100. These values were changed back to the original numbers in the polygon attribute tables of the resulting ARC coverages.

Maps that show changes or differences between an earlier and later date fire scar map were produced using the ERDAS MATRIX overlay. A Landsat MSS composite fire scar map was produced by overlaying all 3 fire scar maps using the ERDAS GIS Modeling program. This map shows all fire scar areas mapped for all combinations of the 3 Landsat scenes.

" RESULTS & DISCUSSION

Geocorrection

Image-to-image registration was checked by displaying 1 image at full resolution--every pixel was displayed for a 1,024 by 1,024 subscene--and then displaying another image without erasing the image already being displayed. As the second image was displayed, linear features remained aligned

indicating the images registered well. Shifts in linear features would have indicated poor image to image registration. Another check of registration was accomplished using the

ARC LIVELINK to overlay the SRBOPA roads GIS coverage onto the image. Roads aligned well between the 2 sources throughout the site indicating good registration.

Spatial Enhancements

The spatial filters were evaluated visually by displaying the filtered images and determining if a fire scar was more visible than on a raw image. None of the filters helped distinguish fire scars. They all degraded the images to varying degrees and made fire scars less visible than on the raw images. The edge filters only delineated boundaries between water and surrounding land indicating that the differences between fire scars and surrounding land are to subtle to be enhanced with an edge filter.

Spectral Enhancements

Both of the Vis degraded overall image quality and did not enhance fire scars probably because most of the land burned had regrown vegetation. And in an arid environment the spectral response of an area is largely influenced by soil reflectance properties (Tueller 1987) thus reducing the value of a VI for enhancing information about the vegetation cover. The value of the Vis may be to help determine burn severity once a fire scar is already mapped (Milne 1986).

PCA produced a PC2 image with image noise for all 3 scenes. The output images did not enhance fire scars and the overall image quality was poor. Fourier Analysis may be used to eliminate image noise (Lillesand and Kiefer 1987), but software to

implement this is not available at the Idaho Department of Water Resources. Further analysis would be required to determine the cause of the image noise.

As previously mentioned, the TC brightness and greenness FCC slightly enhanced and made fire scars more interpretable, than on the raw image 3-band FCC. This is probably because when viewing the raw images only 3 of the 4 bands can be viewed at 1 time, but when viewing the TC images about 95% of the information contained in the raw imagery can be viewed simultaneously with the 2 TC channels.

Fire Scar Mapping Accuracy

Table 2 shows the results of the accuracy assessment. For the 1987 fire year, the 24 May 1988 fire scar map has an accuracy of 63% compared to 31% for the 27 September 1987 map. This suggests that a spring scene is better than a fall scene for assessing fire scars, but for the 1986 to 1981 fire years all 3 scenes produced similar results. It became apparent during this assessment that most fire scars that had been mapped using screen digitizing and stratification were mapped relatively accurately, while fire scars that were inferred from the 2 grassland cover classes were mapped relatively poorly, as compared to the BLM fire scar maps. This suggests that a better classification of grassland would have improved results. The accuracy of the grassland classification was not assessed but it is probably poor in many areas based on the differences between the 3 classifications. Due to the problem with the grassland classification, it is not possible to determine which of the 3 scenes was best for mapping fire scars.

Table 2. Accuracy of Landsat MSS Fire Scar Maps based on the ratio between the number of fire scars detected using Landsat MSS and the total number of fire scars on BLM Fire Scar Maps.

BLM Fire Scar Maps	Landsat MSS		
	20 April 1987	27 September 1987	24 May 1988
1987	-- --	5/16 (31%)	10/16 (63%)
1986	5/12 (42%)	5/12 (42%)	6/12 (50%)
1985	4/13 (31%)	5/13 (38%)	5/13 (38%)
1984	2/18 (11%)	3/18 (17%)	3/18 (17%)
1983	1/20 (5%)	2/20 (10%)	1/20 (5%)
1982	1/10 (10%)	1/10 (10%)	2/10 (20%)
1981	2/12 (17%)	3/12 (25%)	4/12 (33%)
1980	0/1 (0%)	0/1 (0%)	1/1 (100%)

Tables 3, 4, and 5 show the areas of agreement between the Landsat fire scar maps and the BLM composite fire scar map. These were produced with an ERDAS MATRIX overlay. Because these numbers are based on areas, larger fire scars affect the overall results more than small fire scars. Note the relatively high percentage for all the maps for the 1986 fire year. This was because 2 large fire scars were mapped well on all the Landsat fire scar maps as compared to the BLM fire scar maps. The 24 May 1988 map shows the highest percentage accuracy for most years, but it

also shows the highest percentage (20) of fire scar mapped in the BLM map unburned category (Table 6). This is an indicator of commission error. This occurred because more area was classified as grassland, and inferred as fire scar, using the 24 May 1988 Landsat scene than the other 2 scenes. This reinforces the need for an accurate grassland classification if grassland is used to infer fire scars.

After these results were compiled, the imagery was looked at again with the BLM composite fire scar map to help determine

Table 3. Total area (ha) and percent of area classified as fire scar on the 20 April 1987 Landsat MSS fire scar map compared to the composite BLM Fire Scar Map.

BLM Fire Scar Maps		Landsat MSS	
Year	Fire Scars	Fire Scars	Percentage
1987	---	---	---
1986	9,317	6,809	73
1985	11,539	2,850	25
1984	17,218	2,453	14
1983	20,096	1,842	9
1982	2,749	482	18
1981	14,946	2,016	13
1980	123	5	4
TOTAL	75,988	16,457	22

Table 4. Total area (ha) and percent of area classified as fire scar on the 27 September 1987 Landsat MSS fire scar map compared to the composite BLM fire scar map.

BLM Fire Scar Maps		Landsat MSS	
Year	Fire Scars	Fire Scars	Percentage
1987	11,398	1,476	13
1986	9,191	7,044	77
1985	11,444	2,479	22
1984	13,902	2,415	17
1983	18,267	2,685	15
1982	2,747	394	14
1981	14,690	1,126	8
1980	122	0	0
TOTAL	81,761	17,619	18

Table 5. Total area (ha) and percent of area classified as fire scar on the 24 May 1988 Landsat MSS fire scar map compared to the composite BLM fire scar map.

<u>BLM Fire Scar Maps</u>		<u>Landsat MSS</u>	
Year	Fire Scars	Fire Scars	Percentage
1987	11,398	5,860	51
1986	9,191	7,575	82
1985	11,444	3,527	31
1984	13,902	4,162	30
1983	18,267	2,733	15
1982	2,747	639	23
1981	14,690	2,982	20
1980	122	85	70
TOTAL	81,761	27,563	34

Table 6. Total area (ha) and percent of area mapped as fire scar using Landsat MSS that corresponds to unburned areas on the BLM fire scar maps.

<u>BLM Map</u>		<u>Landsat MSS</u>	
Unburned	Years	Fire Scars	Date
145,865	1980-86	19,795 (14%)	20 Apr 1987
140,090	1980-87	14,058 (10%)	27 Sep 1987
140,090	1980-87	27,449 (20%)	24 May 1988

why some of the scars were not mapped correctly. Even in the fire years closest in time (1986 and 1987) to the Landsat acquisition dates some of the fire scars could not be distinguished on the imagery. Perhaps these were light fire scars that were only visible shortly after the fire occurred. A record of fire severity in written or video form would be required to determine the reason. In contrast, some older scars mapped well and were distinguishable on the imagery. This could be due to the severity of the scar or the type of soil and vegetation the fire occurred on, further work would be required to determine the reasons.

Tables 7, 8, and 9 compare Landsat change maps and the 1987 BLM fire scar map. Tables 7 and 8 show the results of change maps that compare pre- and post-fire season

Landsat scenes. Based on these results, the spring to spring map was most accurate (Table 7), with 5,540 ha of the fire scar area mapped, versus 1,312 ha for the spring to fall sequence (Table 8). But the spring to spring map has a higher percentage of fire scars mapped in the area outside of BLM fire scars, 21,808 ha versus 6,569 ha. In summary, the omission error was less for the spring to spring map but the trade-off was a higher commission error because more land was classified as grassland and inferred as fire scar with the spring (24 May 1988) than the fall (27 September 1987) post-fire season map. Once again, this reinforces the need for an accurate grassland classification. Since the 27 September 1987 and 24 May 1988 scenes are both post burn, the resulting map and Table 9 just categorize the differences between these 2 maps.

Table 7. Comparison between the 20 April 1987 to 24 May 1988 Landsat MSS change map and BLM 1987 fire scar map (in ha). The unburned category represents land outside of fire scars.

	Landsat MSS	
	20 Apr 1987 to 24 May 1988	
	Fire Scars	Unburned
BLM 1987		
Fire Scars	5,540	5,859
Unburned	21,808	188,645

Table 8. Comparison between the 20 Apr to 27 Sep 1987 Landsat MSS change map and BLM 1987 fire scar map (in ha). The unburned category represents land outside of fire scars.

	Landsat MSS	
	<u>20 Apr 1987 to 27 Sep 1987</u>	
	Fire Scars	Unburned
<u>BLM 1987</u>		
Fire Scars	1,312	10,086
Unburned	6,569	203,885

A large area classified as fire scar on all 3 Landsat fire scar maps but not on any of the BLM fire maps occurs in the center of the SRBOPA. It appears as a distinct area on the imagery. It probably is composed of low density grass and light soil based on the spectral response of the area. When and if this area was affected by fire is unknown. It may be possible to determine when and if this area was affected by fire by analyzing Landsat MSS scenes back to 1972 and historical aerial photography.

■ CONCLUSION

Fire scars that can be visually identified and screen digitized can be mapped using a stratified classification approach. Fire scars that were inferred from the grassland cover classes were not mapped accurately due to misclassification of grassland. Much more effort needs to be directed to the classification process if grassland will be used to infer fire scar in future projects. Since fire scars that can be visually identified are probably the most severe; it can be concluded that severe fire scars can be mapped back to the early 1970's using the procedures outlined in this report--except

for inferring fire scars from the grassland class of a landcover classification.

An alternative approach may be to use recent Landsat TM data to develop an accurate land cover classification, including grassland to infer previously burned areas, and use Landsat MSS to map only the more severe and visible fire scars back to 1972. This method would offer the advantages of Landsat TM for developing an accurate grassland classification while using Landsat MSS data as a more limited but more reliable source of information.

It is not possible to determine which of the 3 scenes is best for mapping fire scars considering the problems with the grassland classification. Although the 24 May 1988 scene has the best overall accuracy when only commission error is considered, as in the scene-to-scene comparisons (Table 2); it shows a higher commission error rate when commission error is accounted for as in Tables 3, 4, and 5, and Tables 7 and 8. This was caused by the problems with the grassland classification.

The other conclusions are as follows: 1) Spatial and edge filters were not useful for distinguishing fire scars. 2) Vis degraded

Table 9. Comparison between the 27 Sep 1987 to 24 May 1988 Landsat MSS change map and BLM 1987 fire scar map (in ha). The unburned category represents land outside of fire scars.

	Landsat MSS 27 Sep 1987 to 24 May 1988	
	Fire Scars	Unburned
<u>BLM 1987</u>		
Fire Scars	4,530	6,868
Unburned	23,785	186,669

image quality and did not enhance fire scars. The value of Vis may be to determine burn severity for areas already mapped as fire scars but the utility of Vis is degraded in arid environments because spectral characteristics are dominated by soil reflectance. 3) PCA was not useful for enhancing fire scars. Since PCA can produce somewhat unpredictable results the TC is a better choice for reducing data dimensionality. 4) The TC transformation was useful to reduce the dimensionality of the data from 4 raw bands to the 2 TC Brightness and Greenness channels. TC was also useful to slightly enhance fire scars in respect to the raw images and for making the data more interpretable since its output is directly related to the soil and vegetation characteristics in a scene.

Suggestions for further study: 1) Conduct field work in specific fire scars to determine why some recent fire scars could not be

distinguished while some relatively older fire scars were readily distinguished on imagery. 2) Test some of the change detection methods suggested by Milne (1986), Richards and Milne (1983), and Jensen (1986). The multitemporal approaches discussed by these authors will probably improve results over the pre- and post-fire GIS overlay change detection method used in this project. The limitation of these change detection techniques is that they may not be practical to use in long-term applications such as that envisioned for the SRBOPA fire scar mapping efforts. 3) An alternative approach to mapping burns of a current season may be to use the current BLM method, possibly along with color infrared video or single band near-infrared video, and then use Landsat data to more precisely map the burns.



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Monitoring Studies on Greenstrip Projects in the Snake River Birds of Prey Area, 1992

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ANNUAL SUMMARY

Monitoring of greenstrip projects is continuing with data collection at 36 study sites on 10 greenstrip projects. No new study sites were established in 1992. Recruitment of an exotic shrub is occurring at a faster rate than that of a native shrub on a disturbed site.

■ OBJECTIVE

1. To monitor establishment and persistence of plants used to establish strips of fire resistant vegetation (i.e., greenstrips) in the Snake River Birds of Prey Area (SRBOPA).
2. To document competitive interactions between forage kochia and shadscale shrubs.

■ METHODS

Two similar study procedures are used to determine if objectives are being met. Most greenstrip projects are monitored with a procedure that combines cover, density, phenology and frequency data collection. This

procedure, called "Freqdens", is described in a previously published report (Pellant 1989).

Prior to initiation of the "Freqdens" procedure in 1989, selected greenstrip projects were monitored using a pace transect. The same vegetation sampling procedures are utilized with pace transect and "Freqdens" techniques. The primary difference is the use of 5 short belt transects with "Freqdens", versus the use of 1 long pace transect in the pace transect technique. Closeup and general view photographs are taken on all studies.

■ RESULTS AND DISCUSSION

During the 1992 field season, 36 study sites on 10 greenstrip projects were monitored.

Two study sites established in 1990 on an experimental greenstrip near Simco Road were

resampled in 1992. A site preparation and seeding machine (disk chain) was used to seed a crested wheatgrass (*Agropyron cristatum*) and forage kochia (*Kochia prostrata*) mixture in 1986. Forage kochia is an introduced half-shrub that is very competitive with cheatgrass (*Bromus tectorum*) and retains fire resistance throughout the summer. These studies document the competitive interactions between seeded and native species along 4 160-m transects. The transects originate at the greenstrip boundary and run into adjacent rangeland that was burned in a 1986 wildfire.

Numbers of mature forage kochia and shadscale (*Atriplex confertifolia*), the dominant prefire shrub, increased by 32% and 22%, respectively, from 1991 to 1992 (Table 1). Numbers of mature forage kochia and

shadscale plants varied over the 3-year sampling period. This variation is probably a result of inadequate sample size and not a statistically significant variation in numbers of plants. Results from preliminary statistical analysis supports this statement.

Relative recruitment of each shrub can be compared by dividing number of seedlings by the total number of mature plants (Table 2). Relative recruitment values of 0.103 seedlings per mature forage kochia plant were 2.3 times greater than the 0.045 seedlings per mature shadscale plant. Apparently, environmental and/or seedbed conditions were more favorable for establishment of forage kochia seedlings compared to shadscale seedlings.

Detailed evaluation reports for each greenstrip project in the SRBOPA are in draft. These reports include site preparation and seeding descriptions, management actions, climatic information, and monitoring data.

Table 1. Forage kochia and shadscale survival and recruitment, (nos./ha) 1990-92.

	Forage kochia		Shadscale	
	Seedling	Mature	Seedling	Mature
1990	0.0	4,544.8	24.7	1,951.3
1991	123.5	3,260.4	148.2	1,556.1
1992	444.6	4,297.8	86.5	1,901.9

Table 2. Recruitment values for forage kochia and shadscale, 1991-1992.

	<u>Forage kochia</u> (seedlings/mature plant)	<u>Shadscale</u> (seedlings/mature plant)
1991	0.038	0.095
1992	0.103	0.045

■ PLANS FOR NEXT YEAR

Monitoring of selected greenstrip projects in SRBOPA will continue in 1993. Sample size will be increased on the forage kochia and shadscale study to determine if population changes are statistically different.

■ ACKNOWLEDGMENTS

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Germination and Seedling Establishment of Spiny Hopsage (*Grayia spinosa* [Hook.] Moq.)

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ANNUAL SUMMARY

A thesis was completed in March 1992, in partial fulfillment of the requirements for a Doctor of Philosophy degree at Oregon State University. An abstract of the thesis is presented here.

■ OBJECTIVES:

The overall object of this investigation was to determine requirements for establishment of spiny hopsage from seed to maximize returns from rangeland seedings and to obtain rapid and uniform emergence under nursery conditions. Subobjectives include:

1. To review literature relevant to seed biology, seedling establishment, and propagation.
2. To determine effects of planting date, seed source, seedbed preparation, and seedbed environment on seed germination and seedling establishment.

3. To evaluate germination pretreatments to improve speed and uniformity of seedling establishment under greenhouse or nursery conditions.
4. To begin an examination of the nature of seed dormancy in the species.

■ RESULTS

Reestablishment of spiny hopsage (*Grayia spinosa* [Hook.] Moq.) where depleted or lost on shrub steppe sites can improve forage, plant cover, and soil stabilization.

The effects of seed source, planting data, and site preparation method on seed germination and seedling establishment (SE) were examined at Birds of Prey and Reynolds Creek in southwestern Idaho. Three seed sources were planted on rough or compact seedbeds on 4 dates in 1986-87 and 3 dates in 1987-88. Exposure to cool-moist environments improved spring SE from early fall (EF) and late fall (LF) plantings. Few seedlings emerged from early spring (Esp) or late spring (Lsp) plantings. SE was low at 1 site in 1986-87 and at both sites in 1987-88, probably due to lack of precipitation. For the successful 1986-87 planting, seedling density was greater on rough compared to compact seedbeds in April and May, possibly due to improved microclimate conditions. Growth rate varied among seed sources, but seedlings developed a deep taproot (mean length 266 mm) with few lateral roots the first season.

Seeds were planted on 3 dates in 1986-87 and 1987-88, and nylon bags containing seeds were planted on 4 dates each year to study microenvironment effects on germination (G), germination rate (GR), and SE. Bags were recovered on subsequent planting dates, and seeds were tested for moisture content, viability, G, and GR. In

1987-88 with low precipitation, seedlings established only from LF plantings ($< 1/m^2$).

In response to high March 1989 precipitation, establishment was 6 and 26 times greater on LF compared to Esp plantings. Incubating seeds in soil from LF to Esp 1987-88 increased G 6-11 times and GR 12 and 13 days. Incubating seeds in soil from W to Esp increased G 1-6 times and GR 4 and 8 days compared to controls. In 1988-89, incubation from LF to W increased G 17 times and GR 10 and 11 days compared to controls, while incubation from W to Esp increased G 4 and 7 times and GR 10 and 11 days.

Utricles and seeds responded to stratification for 60 days at 3-5 C. Mean G at 5/15 C (44%) was similar to maximum constant temperature G obtained over the 20-30 C (37-40%) range. Embryo excision and mechanical scarification released dormancy imposed by the elastic inner layers of the testa. Moist heat at 35 C reduced dormancy; the effect was greater for seeds than utricles. Dormancy imposed by bracts was not reduced by leaching. Bracts did not inhibit water uptake or provide mechanical restraint to the radicle; they may act by reducing permeability to oxygen or other gases.



Environmental Monitoring in the Idaho Army National Guard Orchard Training Area

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ANNUAL SUMMARY

*Two hundred seventy-nine permanent land condition-trend vegetation/soil monitoring (LCTA) plots established in 1989-1991 were monitored, and small mammals were livetrapped in selected Orchard Training Area microhabitats. One new LCTA special-use plot was established on a *Lepidium papilliferum* site. We searched for and identified *Lepidium papilliferum* microsites north of Range Road/Orchard Road. Fifty photopoints were established and monitored in the north half of the impact area.*

■ OBJECTIVE

To assess and monitor the land condition and mammal populations in the Orchard Training Area in order to minimize the impacts of National Guard training.

■ METHODS

Vegetation/soils monitoring

One new special-use LCTA plot was established inside the OTA, to monitor

population of a federal category 2 candidate plant species, *Lepidium papilliferum* (hereafter called LEPA). The LCTA method was used to establish and monitor these LEPA plots, with the modifications described in last year's annual report (Quinney et al. 1991). This plot, #296, is located east of Range 6.

LEPA plants were counted on the 4 1.6-km walking transects, monitored in early June; also in June, sagebrush communities in the OTA were searched, and a rough count of LEPA plants was made. We searched for

and identified all LEPA microsites in the OTA north of Range Road and Orchard Road. We are now geolocating these sites with a global positioning system. In June, 450 LEPA plants were marked with numbered aluminum tags "nailed" to the soil, to help understand the longevity of individual plants and microsites. These tagged plants will be recounted monthly, unless the plants are snow-covered.

On LCTA core plots where sagebrush occurred as the dominant shrub, belt transects were sampled in 1992. Also, belt transects were sampled on the 8 shrub transplant special-use plots established in 1990. A belt transect was sampled on the special-use plot established in 1992. Shrub belt transects were monitored using the methods outlined in this section of the 1990 Birds of Prey annual report (Quinney 1990). All native shrubs were counted on 1990 transplant special-use plots, using the methods reported in the 1990 Birds of Prey annual report (Quinney et al. 1990). A more detailed explanation of the LCTA methods used in the Orchard Training Area can be found in the U.S. Army Land Condition Trend Analysis (LCTA) Field Methods manual (U.S. Army Corps of Engineers 1987).

A plant species not previously recorded from the OTA was collected and identified: sagebrush buttercup, *Ranunculus glaberrimus* Hook., which was found on and near the Study 4 trapping sites east of Standifer Road.

In April and May, the remaining photopoint locations in the north polygon formed by Range Road and the livestock drift fence

were established; all 50 photopoints were geolocated and photographed, using the procedure outlined in last year's annual report (Quinney et al. 1991).

Small mammal monitoring

We did not snap-trap mammals this year, but concentrated on the inventory of microhabitats not plot-selected by the LCTA method. Beginning in mid-June and ending in late September, we livetrapped 4 rock-outcrop microhabitats, a dense sage habitat, and a shadscale habitat in the OTA. We used 40 folding Sherman traps with oatmeal for bait, and 10 larger wire mesh livetraps baited with cabbage and apple. Sites were trapped on 2 consecutive nights. Animals were released at the trapping sites.

In June and July, the 60 mammal trapping plots sampled in previous years were censused for Townsend's ground squirrel (*Spermophilus townsendii*, hereafter TGS) and badger (*Taxidea taxus*) holes, using the method described in the 1990 annual report (Quinney 1990).

In 1992, we did not monitor OTA reptiles.

■ RESULTS

Vegetation/soils monitoring

In 1992, 280 LCTA plots were inventoried. One additional plot was created. Analysis of LCTA-plot soil samples is still under way. On the 8 native shrub transplant sites established in 1990, all shrub seedlings were counted.

Walking surveys were done to provide a rough estimate of 1992 LEPA numbers in the OTA; approximately 15,000 living individuals were counted.

Information collected on LEPA in 1992 is on file in Boise, Idaho, at the Army National Guard Environmental Management Office, with Dr. Roger Rosentreter, Idaho State Office of the Bureau of Land Management, with Dr. Robert Parenti, U.S. Fish and Wildlife Service, and with Robert Moseley, Idaho State Department of Fish and Game. A Trimble Pathfinder global positioning unit is being used to geolocate LEPA microsites.

LCTA data collected are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

Herbarium voucher specimens of *Ranunculus glaberrimus* Hook. will be archived in the herbarium of Colorado State University, Fort Collins, Colorado.

Small mammal monitoring

The 1992 mammal survey resulted in the capture of the following species in the Orchard Training Area: *Tamias minimus*, *Dipodomys microps*, *Dipodomys ordii*, *Onychomys leucogaster*, *Perognathus*

parvus, *Peromyscus maniculatus*, *Reithrodontomys megalotis*, *Sylvilagus nuttallii*, and *Spermophilus townsendii*. Added to the OTA mammal species list in 1992 was *Mustela erminea*. A short-tailed weasel was livetrapped in September near plot #143, Orchard Corner, a rock outcrop in a big sagebrush habitat. 1992 mammal capture data, when compiled, will be filed in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, at the Idaho Department of Fish and Game, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

Black-tailed jackrabbit censusing was done as part of the BLM Snake River Birds of Prey Area monitoring effort, and OTA results are included in the section of this annual report that reports jackrabbit abundance in the Snake River Birds of Prey Area.

Townsend's ground squirrel and badger monitoring

Sixty hole count transects were sampled during June and July 1992. TGS and badger hole count data, when compiled, will be on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.



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